DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 545

BIBLIOGRAPHY

OF

NORTH AMERICAN GEOLOGY

FOR

1912

WITH SUBJECT INDEX

BY

JOHN M. NICKLES

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

CONTENTS.

	Page.
Introduction	5
Serials examined	6
Bibliography	11
Classified scheme of subject headings	114
Index	117
Lists	164
Chemical analyses	164
Minerals described	166
Rocks described	169
Geologic formations described	170

BIBLIOGRAPHY OF NORTH AMERICAN GEOLOGY FOR 1912, WITH SUBJECT INDEX.

By John M. Nickles.

INTRODUCTION.

The bibliography of North American geology, including paleontology, petrology, and mineralogy, for the year 1912, follows the plan and arrangement of its immediate predecessors, the bibliographies for 1906–7, 1908, 1909, 1910, and 1911 (Bulletins 372, 409, 444, 495, and 524 of the U. S. Geological Survey). It includes publications bearing on the geology of the Continent of North America and adjoining islands, also Panama and the Hawaiian Islands. Papers by American writers on the geology of other parts of the world are not included. Textbooks and papers general in character by American authors are included; those by foreign authors are excluded unless they appear in American publications.

As heretofore, the papers, with full title and medium of publication and explanatory note when the title is not fully self-explanatory, are listed under the authors, arranged in alphabetic order. The author list is followed by an index to the literature listed. In this index the entries in one alphabet are of three kinds—first, subject, with various subdivisions, to enable the specialist to ascertain readily all the papers bearing on a particular subject or area; second, titles of papers, many of them abbreviated or inverted, under their leading words; and third, cross references, which have been freely used to avoid too much repetition. The subjects have been printed in black-faced type, the titles of papers and cross references in ordinary type. As it may not be always obvious which subject headings have been adopted, a classified scheme of those used immediately precedes the index.

Miss Isabel P. Evans has given efficient assistance in preparing the material for the press.

The bibliography of North American geology is comprised in the following bulletins of the United States Geological Survey: No. 127 (1732–1892); Nos. 188 and 189 (1892–1900); No. 301 (1901–1905); No. 372 (1906–7); No. 409 (1908); No. 444 (1909); No. 495 (1910); No. 524 (1911); and No. 545 (1912).

SERIALS EXAMINED.

Academy of Natural Sciences of Philadelphia: Proceedings, vol. 63, pt. 3, vol 64, pts. 1, 2; Journal, 2d ser., vol. 14, pt. 4, vol. 15. Philadelphia, Pa.

Academy of Science of St. Louis: Transactions, vol. 20, no. 7; vol. 21, nos. 1–3. St. Louis, Mo.

Alabama Geological Survey: Bulletin, no. 12. Montgomery, Ala.

American Academy of Arts and Sciences: Proceedings, vol. 47, nos. 13–22, vol. 48, nos. 1–13. Boston, Mass.

American Geographical Society: Bulletin, vol. 44. New York.

American Institute of Mining Engineers: Bulletin, nos. 61–72; Transactions, vol. 42. New York.

American Journal of Science, 4th ser., vols. 33, 34. New Haven, Conn.

American Museum of Natural History: Memoirs, new ser., vol. 1, pts. 1–3; Bulletin, vol. 31; Journal, vol. 12. New York.

American Naturalist, vol. 46. New York.

American Philosophical Society: Proceedings, vol. 51, nos. 203–207. Philadelphia, Pa.

American Year Book for 1911. New York.

Annales de Paléontologie, t. 7. Paris, France.

Annales des Mines, 11ᵉ sér., t. 1, 2. Paris, France.

Annals and Magazine of Natural History, 8th ser., vols. 9, 10. London.

Appalachia, vol. 12, no. 4. Boston, Mass.

Association of Engineering Societies: Journal, vols. 48, 49. Boston, Mass.

Bernice Pauahi Bishop Museum: Occasional Papers, vol. 5, nos. 1, 2. Honolulu, Hawaiian Islands.

Boston Society of Natural History: Proceedings, vol. 34, no. 13; Memoirs, vol. 7. Boston, Mass.

Botanical Gazette, vols. 53, 54. Chicago, Ill.

British Columbia, Bureau of Mines: Annual Report of the Minister of Mines for 1911. Victoria, B. C.

Buffalo Society of Natural Science: Bulletin, vol. 2, no. 2. Buffalo, N. Y.

California Academy of Scienees: Proceedings, 4th ser., vol. 1, pp. 323–446, vol 3, pp. 147–264. San Francisco, Cal.

California State Mining Bureau: Bulletin, no. 64. San Francisco, Cal.

California, University of, Department of Geology: Bulletin, vol. 7, nos. 1–8; Memoirs, vol. 1, no. 2. Seismographic Stations: Bulletin, nos. 1–3. Berkeley, Cal.

Canada, Geological Survey: Summary Report for 1911; Memoirs, 13, 17, 18, 21, 24, 27, 28, 35. Ottawa, Ont.

Canada, Department of Mines, Mines Branch: Summary Report for 1911; Bulletin, nos. 7–8; and miscellaneous publications. Ottawa, Ont.

Canadian Institute: Transactions, vol. 9, pts. 2, 3. Toronto, Ont.

Canadian Mining Institute: Quarterly Bulletin, nos. 18–20; Journal, vols. 14, 15, pt. 1. Ottawa, Ont.

Canadian Mining Journal, vol. 33. Toronto and Montreal, Canada.
Carnegie Institution of Washington: Yearbook, no. 10, for 1911. Washington, D. C.
Carnegie Museum: Annals, vol 8, no. 2; Memoirs, vol. 5. Pittsburgh, Pa.
Cassier's Magazine, vol. 41, vol. 42, nos. 1–6. New York.
Centralblatt für Mineralogie, Geologie, und Paleontologie, Jahrgang 1912. Stuttgart, Germany.
Cincinnati Society of Natural History: Journal, vol. 21, no. 3. Cincinnati, Ohio.
Coal Age, vols. 1, 2. New York.
Colorado College Publications: Science series, vol. 12, nos. 10, 11. Colorado Springs, Colo.
Colorado Geological Survey: Bulletin 3. Denver, Colo.
Colorado School of Mines Magazine, vol. 2, nos. 4–15; Quarterly, vol. 6, no. 4, vol. 7, nos. 1–4. Golden, Colo.
Colorado Scientific Society: Proceedings, vol. 10, pp. 123–210. Denver, Colo.
Colorado, University of: Studies, vol. 9, nos. 1–4. Boulder, Colo.
Connecticut State Geological and Natural History Survey: Bulletin, nos. 19, 21. Hartford, Conn.
Delaware County Institute of Science: Proceedings, vol. 6, nos. 3–4. Media, Pa.
Denison University, Scientific Laboratories: Bulletin, vol. 17, pp. 1–201. Granville, Ohio.
Deutsche Geologische Gesellschaft: Monatsberichte, nos. 1–12; Zeitschrift, Bd. 63, H. 4, Bd. 64, H. 1–3. Berlin, Germany.
Economic Geology, vol. 7. Lancaster, Pa.
Elisha Mitchell Scientific Society: Journal, vol. 28, nos. 1–3. Chapel Hill, N. C.
Engineering Association of the South: Proceedings, vol. 23, nos. 1–4. Nashville, Tenn.
Engineering and Mining Journal, vols. 93, 94. New York.
Engineering Magazine, vol. 42, nos. 4–6, vol. 43, vol. 44, nos. 1–3. New York.
Engineers' Club of Philadelphia: Proceedings, vol. 29. Philadelphia, Pa.
Engineers' Society of Western Pennsylvania: Proceedings, vol. 27, no. 10, vol. 28, nos. 1–9. Pittsburgh, Pa.
Field Museum of Natural History: Geological series, vol. 4, no. 2. Chicago, Ill.
Florida State Geological Survey: Fourth Annual Report; Bulletin, no. 2. Tallahassee, Fla.
Franklin Institute: Journal, vols. 173, 174. Philadelphia, Pa.
Geographical Journal, vols. 39, 40. London.
Geographical Society of Philadelphia: Bulletin, vol. 10. Philadelphia, Pa.
Geological Magazine, new ser., decade 5, vol. 9. London.
Geological Society of America: Bulletin, vol. 23. New York.
Geological Society of London: Quarterly Journal, vol. 68. London.
Geologische Rundschau, Bd. 3. Leipzig, Germany.
Geologists' Association, London: Proceedings, vol. 23. London.
Georgia Geological Survey: Bulletin, nos. 27, 28. Atlanta, Ga.
Hamilton Scientific Association: Journal and Proceedings, no. 27. Hamilton, Ont.
Harvard College, Museum of Comparative Zoology: Bulletin, vol. 53, nos. 7–9, vol. 54, nos. 10–15, vol. 55, no. 1, vol. 56, no. 1, vol. 57, no. 1; Memoirs, vol. 27, no. 4, vol. 34, no. 4, vol. 35, nos. 3–4, vol. 40, nos. 4–5, vol. 44, no. 1. Cambridge, Mass.
Illinois State Academy of Science: Transactions, vol. 4. Springfield, Ill.
Illinois State Geological Survey: Bulletin, nos. 17–19. Urbana, Ill.
Illinois State Laboratory of Natural History: Bulletin, vol. 9, art. 5. Urbana, Ill.

Imperial Earthquake Investigation Committee: Bulletin, vol. 4, no. 3, vol. 6, no. 1. Tokyo, Japan.

Indiana Academy of Science: Proceedings for 1911. Indianapolis, Ind.

Indiana, Department of Geology and Natural Resources: 36th Annual Report. Indianapolis, Ind.

Institution of Mining Engineers: Transactions, vol. 41, pt. 7, vol. 42, pts. 2–6, vol. 43, pts. 1–7, vol. 44, pt. 1. Newcastle upon Tyne, England.

Iowa Academy of Sciences: Proceedings, vol. 19. Des Moines, Iowa.

Iowa Geological Survey: Annual Report for 1910–11, vol. 21. Des Moines, Iowa.

Journal of Geography, vol. 10, nos. 5–9. Lancaster, Pa.

Journal of Geology, vol. 20. Chicago, Ill.

Kentucky Geological Survey: Report on Progress of Survey, 1910–11: Bulletin, nos. 10–14, 17–18, 20–21. Lexington, Ky.

Lake Superior Mining Institute: Proceedings, vol. 17. Ishpeming, Mich.

Meddelelser om Groenland, H. 36, 38, Bd. 42, 45, 46, no. 1, 48, 49, 50. Copenhagen, Denmark.

Mexico, Instituto Geológico: Parergones, t. 4, no. 1; Boletín, no. 29. Mexico, D. F.

Michigan Geological and Biological Survey: Publications 6, 8, 9 (Geological series, 4, 6, 7). Lansing, Mich.

Mineralogical Magazine and Journal of the Mineralogical Society, vol. 16 (no. 75). London.

Mines and Methods, vol. 3, nos. 5–12, vol. 4, nos. 1–4. Salt Lake City, Utah.

Mines and Minerals, vol. 32, nos. 6–12, vol. 33, nos. 1–5. Scranton, Pa.

Mining and Metallurgical Society of America: Bulletin, nos. 44–55. New York.

Mining and Scientific Press, vols. 104, 105. San Francisco, Cal.

Mining Magazine, vols. 6, 7. London.

Mining Science, vols. 65, 66. Denver, Colo.

Mining Society of Nova Scotia, vol. 17. Halifax, N. S.

Mining and Engineering World, vols. 36, 37. Chicago, Ill.

Mississippi State Geological Survey: Third Biennial Report; Report on the iron ores of Marshall and Benton counties. Jackson, Miss.

Missouri Bureau of Geology and Mines, 2d ser., vols. 10, 11. Jefferson City, Mo.

National Geographic Magazine, vol. 23. Washington, D. C.

Nature, vol. 88 (no. 2201)–vol. 90 (no. 2252). London.

Nautilus, vol. 25, nos. 9–12, vol. 26, nos. 1–8. Philadelphia, Pa.

Nebraska Geological Survey, vol. 7, pts. 3–5. Lincoln, Nebr.

Neues Jahrbuch für Mineralogie, etc., 1912; Beilage Band, 33, 34. Stuttgart, Germany.

New Brunswick Natural History Society: Bulletin, no. 29 (vol. 6, pt. 4). St. John, N. B.

New Jersey Geological Survey: Bulletin, nos. 6, 7. Trenton, N. J.

New York Academy of Sciences: Annals, vol. 21, pp. 177–263, vol. 22, pp. 1–337. New York.

New York Botanical Garden: Bulletin, vol. 8, nos. 27, 28. New York.

New York State Museum: Bulletin, nos. 155–161; Memoir 14; 64th Annual Report, vols. 1, 2. Albany, N. Y.

North Carolina Geological and Economic Survey, vol. 3; Economic Paper, nos. 25–26, 28–31. Raleigh, N. C.

Nova Scotia Institute of Science: Proceedings and Transactions, vol. 12, pt. 3, vol. 13, pts. 1, 2.

Ohio Geological Survey: Fourth Series, Bulletins 14–16. Columbus, Ohio.

Ohio Naturalist, vol. 12, nos. 3–8, vol. 13, nos. 1–2. Columbus, Ohio.

Ohio State Academy of Science: Proceedings, vol. 5, pts. 9, 10, vol. 6, pt. 1. Columbus, Ohio.

Oklahoma Geological Survey: Bulletin, nos. 9, 15, 16. Norman, Okla.

Ontario Bureau of Mines: Report, vol. 21, pts. 1, 2. Toronto, Ont.

Ottawa Naturalist, vol. 25, nos. 10–12; vol. 26, nos. 1–9. Ottawa, Ont.

Oregon State Bureau of Mines: Bulletin, no. 1 (2d ed.). Corvallis, Oreg.

Palaeobotanische Zeitschrift, Bd. 1, H. 1. Berlin.

Paleontographica, Bd. 59; Supplement IV, L. 3. Stuttgart, Germany.

Pennsylvania, Topographic and Geologic Survey: Report no. 5. Harrisburg, Pa.

Popular Science Monthly, vols. 80, 81. New York.

Québec, Bureau des Mines: Miscellaneous publications. Quebec, Can.

Rochester Academy of Science: Proceedings, vol. 5, pp. 39–58. Rochester, N. Y.

Royal Society of Canada: Proceedings and Transactions, 3d ser., vol. 5. Ottawa, Ont.

School of Mines Quarterly, vol. 33, nos. 2–4, vol. 34, no. 1. New York.

Science, new ser., vols. 35, 36. New York.

Science Conspectus, vol. 2, nos. 2–3, vol. 3, no. 1. Boston, Mass.

Seismological Society of America: Bulletin, vol. 2. Stanford University, Cal.

Sierra Club Bulletin, vol. 8, nos. 3, 4. San Francisco, Cal.

Smithsonian Institution: Annual Report for 1911; Miscellaneous Collections, vol. 56, nos. 29–37, vol. 57, nos. 6–10, vol. 58, no. 2, vol. 59, nos. 1–18, 20, vol. 60, nos. 1–14. Washington, D. C.

Sociedad científica "Antonio Alzate": Memorias y Revista, t. 30, nos. 7–12, t. 31, nos. 1–6. Mexico, D. F.

Société de géographie de Québec: Bulletin, vol. 6. Quebec, Canada.

Société géologique de Belgique: Annales, t. 38, l. 4, t. 39, 1–3. Liege, Belgium.

Société géologique de France: Bulletin, t. 11, t. 12, nos. 1–6. Paris, France.

South Dakota Geological Survey: Bulletin, no. 5. Vermilion, S. D.

Southern California Academy of Sciences: Bulletin, vol. 11, nos. 1, 2. Los Angeles, Cal.

Staten Island Association of Arts and Sciences: Proceedings, vol. 3, pts. 3–4. Staten Island, N. Y.

Tennessee State Geological Survey: Bulletin, 10–B, 14, 15; Resources of Tennessee, vol. 2. Nashville, Tenn.

Texas, University of: Bulletin, Scientific series, no. 23. Austin, Tex.

Torrey Botanical Club: Bulletin, vol. 39. Lancaster, Pa.

Torreya, vol. 12. Lancaster, Pa.

Tschermaks Mineralogische und Petrographische Mitteilungen, N. F., Bd. 31, H. 1–3.

U. S. Bureau of Mines: First Annual Report; Bulletin, nos. 10, 15, 18, 23, 25, 36, 41, 43, 44, 47, 49; Technical Papers, nos. 8, 10, 11, 18, 22–24, 26, 27, 29. Washington, D. C.

U. S. Dept. of Agriculture: Field Operations of the Bureau of Soils; Eleventh Report. Washington, D. C.

U. S. Geological Survey: 33d Annual Report: Bulletins 471, 485, 492, 494, 496–504, 506–521, 523, 524; Water-Supply Papers 259, 279–285, 289–291, 293–296, 298, 299, 301, 304, 311; Professional Papers 69, 71, 74, 77; Geologic Atlas of the United States, folios 179–186; Mineral Resources of the United States for 1911. Washington, D. C.

U. S. National Museum: Proceedings, vol. 41, pp. 413–719, vol. 42, vol. 43, pp. 1–597; Bulletin, no. 79. Washington, D. C.

Vermont Geological Survey: Eighth Report, 1911–1912. Burlington, Vt.

Virginia Geological Survey: Administrative Report, 1910–1911; Bulletin, no. IV. Charlottesville, Va.

Virginia, University of, Publications: Bulletin of the Philosophical Society, Scientific series, vol. 1, nos. 7–8, 10–12. Charlottesville, Va.

Washington Academy of Sciences: Journal, vol. 2. Washington, D. C.

Washington Geological Survey: Bulletin, nos. 3, 7, 9, 14, 15. Olympia, Wash.

West Virginia Geological Survey: County reports—Doddridge and Harrison counties. Morgantown, W. Va.

Western Society of Engineers: Journal, vol. 17. Chicago, Ill.

Wisconsin Geological and Natural History Survey: Bulletin, no. 25; Eighth Biennial Report. Madison, Wis.

Wisconsin Natural History Society: Bulletin, new ser., vol. 10. Milwaukee, Wis.

Wyoming [Geological Survey]: Series B, Bulletin, nos. 3, 4. Cheyenne, Wyo.

Wyoming Historical and Geological Society: Proceedings and Collections, vol. 12. Wilkes-Barre, Pa.

Zeitschrift für Gletscherkunde, Bd. 6, H. 3–5, Bd. 7, H. 1. Berlin, Germany.

Zeitschrift für Krystallographie, Bd. 50, H. 2–6, Bd. 51, H. 1–5. Leipzig, Germany.

Zeitschrift für praktische Geologie, Jahrgang 20. Berlin, Germany.

BIBLIOGRAPHY.

Abele, Charles Arthur.

1. Statistics of the mineral production of Alabama for 1910; compiled from Mineral Resources of the United States: Alabama Geol. Survey, Bull. no. 12, 51 pp., 1912.

Adams, Cyrus C.

2. Cartography: American Year Book, 1911, pp. 601–603, 1912.

Reviews the progress in cartography during the year 1911.

Adams, Frank D.

3. An experimental contribution to the question of the depth of the zone of flow in the earth's crust: Jour. Geology, vol. 20, no. 2, pp. 97–118, 2 pls., 2 figs., February–March, 1912.

The iron ore resources of the world: Canadian Min. Inst., Jour., vol. 14, pp. 215–235, 1912. See no. 1 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 11.

Akin, A. D.

4. Mineral resources of Honduras, Central America: Min. and Eng. World, vol. 36, pp. 865–866, April 20, 1912.

Alden, William C.

5. Pre-Wisconsin glacial drift in the region of Glacier National Park, Montana (with discussion by A. P. Coleman and W. W. Atwood, on pp. 730–731): Geol. Soc. America, Bull., vol. 23, no. 4, pp. 687–708, 4 pls., November 28, 1912; Abstract, Science, new ser., vol. 35, p. 314, February 23, 1912.
6. Sketch of the geological history of Green Lake County, Wisconsin: School Quart., Berlin, Wis., vol. 3, no. 2, pp. 2–14, 8 figs., March, 1912.

Alder, A.

7. Tin: occurrences in the Black Hills and methods of analysis: Pahasapa Quart. (Rapid City, S. Dak.), vol. 1, no. 4, pp. 22–27, June, 1912.

Alfaro, Anastasio, **Michaud**, Gustavo, and **Biolley**, Pablo.

8. Informe sobre el terremoto de Toro Amarillo, Grecia: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 35–41, 5 figs., 1912.

Describes an earthquake of August 28, 1911, in Costa Rica.

Allan, John Andrew.

9. Geology of Field map area, Yoho Park, B. C.: Canada Geol. Survey, Summ. Rept., 1911, pp. 175–187, 1 fig., 1912.
10. Geology of the Ice River district, British Columbia. Abstract of thesis, Massachusetts Institute of Technology. 12 pp. [Boston?], 1912.

Southern Vancouver Island, British Columbia. See Clapp and Allan, no. 185.

Allen, E. T., and Crenshaw, J. L.

11. The sulphides of zinc, cadmium, and mercury: their crystalline forms and genetic conditions; microscopic study by H. E. Merwin: Am. Jour. Sci., 4th ser., vol. 34, pp. 341–396, October, 1912.

Allen, E. T., Crenshaw, J. L., and Johnston, John.

12. The mineral sulphides of iron; with crystallographic study, by Esper S. Larsen: Am. Jour. Sci., 4th ser., vol. 33, pp. 169–236, 23 figs., March, 1912. Abstract (by E. T. A.), Washington Acad. Sci., Jour., vol. 2, no. 1, pp. 9–12, January 4, 1912.

Allen, R. C.

The iron mining industry of Michigan; Michigan gold. See Allen and others no. 13.

Allen, R. C., and others.

13. Mineral resources of Michigan with statistical tables of production and value of mineral products for 1910 and prior years: Michigan Geol. and Biol. Survey, Pub. 8 (Geol. ser. 6), 465 pp., 21 pls., 19 figs., 1912.

Includes sections on the copper industry by R. E. Hore, the iron mining industry by R. C. Allen, the pig iron industry by A. E. White, coal by R. A. Smith, the salt industry by Chas. W. Cook, cement by Chas. W. Cook, gold by R. C. Allen, oil and gas by R. A. Smith.

Allin, Arthur Everett.

Do the Abietineæ extend to the Carboniferous? See Thomson and Allin, no. 1084.

Anderson, Amil A.

14. Lithium, its occurrence, uses, determination, and methods of extraction: Pahasapa Quart. (Rapid City, S. Dak.), vol. 1, no. 3, pp. 11–15, April, 1912.

Anderson, Robert.

15. Preliminary report on the geology and possible oil resources of the south end of the San Joaquin Valley, California: U. S. Geol. Survey, Bull. 471, pp. 106–136, 1 pl. (map), 1912.

16. [The formation of a new island near Trinidad]: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, p. 108, February 19, 1912.

17. The origin and geological occurrence of petroleum: Abstract, Technologist, vol. 17, no. 4, pp. 62–63, April, 1912.

Anderson, Tempest.

18. Volcanic craters and explosions: Geog. Jour., vol. 39, no. 2, pp. 123–132, 8 pls., February, 1912.

Anrep, A.

19. Investigation of the peat bogs and peat industry of Canada, 1910–11: Canada, Dept. Mines, Mines Branch, Bull. no. 8, 53 pp., 19 pls., 1 fig., 12 maps (in separate cover), 1912.

Arber, E. A. Newell.

20. A note on some fossil plants from Newfoundland: Cambridge Philos. Soc., Proc., vol. 15, pt. 5, pp. 390–392, 2 figs., 1910.

21. On *Psygmophyllum majus* sp. nov. from the Lower Carboniferous rocks of Newfoundland, together with a revision of the genus and remarks on its affinities: Linnean Soc. London, Trans., 2d ser., Botany, vol. 7, pt. 18, pp. 391–407, 3 pls., 1 fig., July, 1912.

Ardley, Edward.

22. The occurrence of Ostrea in the Pleistocene deposits of the vicinity of Montreal: Ottawa Naturalist, vol. 26, nos. 5–6, p. 67, August–September, 1912.

Arey, Melvin F.

23. History of geology in Iowa for the last twenty-five years; Iowa Acad. Sci. Proc., vol. 19, pp. 65–72, 1912.

Underground water resources of Iowa. See Norton and others, no. 800.

Ashley, George H.

24. Stratigraphic study of the Appalachian and Central states with reference to the occurrence of oil and gas: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, pp. 725–726, December 17, 1912.

25. A stratigraphic study of the Appalachian and Central states with reference to the occurrence of oil and gas: Abstract, Science, new ser., vol. 35, p. 312, February, 1912.

26. Where may oil and gas be found in Tennessee?: Tennessee State Geol. Survey, Resources of Tennessee, vol. 2, no. 7, pp. 262–272, 2 pls., July, 1912.

27. Bauxite mining in the State of Tennessee: Min. Science, vol. 65, pp. 8–9, January 4, 1912.

28. Aluminum and bauxite mining in Tennessee: Min. and Eng. World, vol. 36, pp. 557–558, 1 fig., March 9, 1912.

Atwood, Wallace W.

29. Some Triassic fossils from southeastern Alaska: Jour. Geology, vol. 20, no. 7, pp. 653–655, 1912.

30. A geographic study of the Mesa Verde: Am. Geog. Soc., Bull., vol. 44, no. 8, pp. 593–598, August, 1912.

Includes notes on the geology and origin of the Mesa Verde, Colorado.

31. Geology and mineral resources of parts of the Alaska Peninsula: Abstract. Washington Acad. Sci., Jour., vol. 2, no. 3, pp. 85–86, February 4, 1912.

Some glacial deposits east of Cody, Wyoming (discussion). See Sinclair, no. 984.

Atwood, Wallace W., and **Mather**, Kirtley F.

32. The evidence of three distinct glacial epochs in the Pleistocene history of the San Juan Mountains, Colorado: Jour. Geology, vol. 20, no. 5, pp. 385–409, 4 figs., July–August, 1912; Abstracts, Science, new ser., vol. 35, p. 315, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 732, December 17, 1912.

Aubury, Lewis E.

33. Biennial report of the state mineralogist [for 1908–9 and 1909–10]: California State Min. Bur., Rept. Board of Trustees, pp. 11–24, 1910.

An administrative report.

Baelz, Walter.

34. The gold fields of New Ontario: Canadian Min. Jour., vol. 33, pp. 299–304, 4 figs., May 1, 1912.

Bagg, Rufus Mather, jr.

35. Pliocene and Pleistocene Foraminifera from southern California: U. S. Geol. Survey, Bull. 513, 153 pp., 38 pls., 3 figs., 1912.

36. Effect of rapid offshore deepening on lake-shore deposits: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 746, December 17, 1912.

Bailey, Irving W.

37. A Cretaceous Pityoxylon with marginal tracheides: Annals of Botany, vol. 25, no. 98, pp. 315–325, 1 pl., April, 1911.

Describes structural features of Pityoxylon from the upper Cretaceous of New Jersey.

Bailey, L. W.

38. Upon some curious structures in the gypsum of Albert County, New Brunswick: Roy. Soc. Canada, Proc. and Trans., 3d ser., vol. 5, sec. 4, pp. 121–124, 2 pls., 1912.

Baker, Charles Laurence.

39. Physiography and structure of the western El Paso Range and the southern Sierra Nevada: California, Univ., Dept. Geology, Bull., vol. 7, no. 6, pp. 117–142, 3 pls., December 4, 1912.

40. Notes on the Cenozoic history of central Wyoming: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, pp. 73–74, March 14, 1912.

Baker, Frank Collins.

41. Postglacial life of Wilmette Bay, Glacial Lake Chicago: Illinois Acad. Sci., Trans., vol. 4, pp. 108–116, 1 fig., 1912.

Describes the successive deposits laid down in the Glacial Lake Chicago, near Chicago, Ill., and the fauna and flora then prevailing as shown by the remains collected from the different beds.

Baker, M. B.

The iron ores of the Mattagami River [Ontario]: Canadian Min. Inst., Jour., vol. 14, pp. 299–309, 3 pls., 1912. See no. 48 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 14.

Bancroft, J. Austen.

42. Geology and natural resources of the basins of the Harricanaw and Nottaway rivers, northwestern Quebec: Quebec (Province), Dept. Colonization, Mines, and Fisheries, Mines Branch, 16 pp. (French edition, 19 pp.), 1 pl. (map), 1912.

43. Report on the geology and mineral resources of Keekeek and Kewagama lakes region: Quebec (Province), Mines Branch, Rept. on mining operations during 1911, pp. 160–207, 6 pls., 1912.

Bancroft, Howland.

44. A nickel deposit in the San Poil mining district, Washington: Min. and Sci. Press, vol. 104, pp. 144–145, January 20, 1905.

Barbour, Erwin H.

45. Notice of newly discovered eurypterids in Nebraska: Science, new ser., vol. 36, pp. 642–643, November 8, 1912.

Barnett, V. H.

46. Some small natural bridges in eastern Wyoming: Jour. Geology, vol. 20, no. 5, pp. 438–441, 3 figs., July–August, 1912.

Barrell, Joseph.

47. Central Connecticut in the geologic past: Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 12, pp. 25–54, 5 pls., 1912.

48. Criteria for the recognition of ancient delta deposits (with discussion by J. M. Clarke, David White, G. W. Stose, Arthur Keith, E. T. Wherry, and H. B. Kümmel, on pp. 743–746): Geol. Soc. America, Bull., vol. 23, no. 3, pp. 377–446, 4 figs, September 12, 1912; Abstract, Science, new ser., vol. 35, p. 317, February 23, 1912.

Discusses the formation of deltas and the criteria by which delta deposits in geologic formations may be recognized.

Barrett, Edward.

49. Glaciation in its relation to the soils of Indiana: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 11–30, 1 pl. (map), 7 figs., 1912.

Barton, George H.

50. Bibliography of W. H. Niles: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 34–35, 1 pl. (port.), March 14, 1912.

Bascom, F.

51. The petrographic province of Neponset Valley, Massachusetts: Acad. Nat. Sci., Philadelphia, Jour., 2d ser., vol. 15, pp. 129–161, 1912.

Bassler, R. S.

52. Proceedings of the third annual meeting of the Paleontological Society, held at Washington, D. C., December 28, 29, and 30, 1911: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 77–92, March 14, 1912.

Bassler, R. S., and others.

53. Symposium of ten years' progress in vertebrate paleontology: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 155–266, June 1, 1912.

Bastin, Edson S.

54. The graphite deposits of Ceylon; a review of present knowledge with a description of a similar graphite deposit near Dillon, Montana: Econ. Geology, vol. 7, no. 5, pp. 419–443, 1 pl., 5 figs., August, 1912.

55. Graphite: U. S. Geol. Survey, Min. Res. U. S., 1911, pt. 2, pp. 1079–1112, 3 figs., 1912.

56. Geology of the Penobscot River basin, Maine: U. S. Geol. Survey, Water-Supply Paper 279, pp. 11–12, 1912.

Bateman, A. M.

57. Geology of Fraser Canyon and vicinity, B. C., Siwash Creek area: Canada Geol. Survey, Summ. Rept., 1911, pp. 125–129, 1912.

Geologic features of tin deposits. See Ferguson and Bateman, no. 322.

Bayley, W. S.

58. A peculiar hematite ore on the tract of the Durham mine, Durham, Penna.: Econ. Geology, vol. 7, no. 2, pp. 179–184, February–March, 1912.

Beattie, H. M.

59. Acme graphite mines and mills [Chester Co., Pa.]: Eng. and Min. Jour., vol. 94, pp. 115–118, 3 figs., July 20, 1912.

Becker, George F.

60. Major C. E. Dutton [1841–1912]: Am. Jour. Sci., 4th ser., vol. 33, pp. 387–388, April, 1912.

Biographical notice of Samuel Franklin Emmons: Am. Inst. Min. Eng., Trans., vol. 42, pp. 643–661, 1 pl. (port.), 1912. See no. 86 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Beede, J. W.

61. [Report on the fossils of the Ames limestone of Harrison County, West Virginia]: West Virginia Geol. Survey, Doddridge and Harrison counties, pp. 254–255., 1912.

Gives a list of Carboniferous fossils identified from the Ames limestone.

62. Origin of the sediments and coloring matter of the red beds of Oklahoma: Science, new ser., vol., 35, pp. 348–350, March 1, 1912; Abstract, Science, new ser., vol. 35, p. 311, February, 1912; abstract (with discussion by I. C. White): Geol. Soc. America, Bull., vol. 23, no. 4, pp. 723–724, December 17, 1912.

Beekly, A. L.

63. The Culbertson lignite field, Valley County, Montana: U. S. Geol. Survey, Bull. 471, pp. 319–358, 3 pls. (maps and sections), 1 fig., 1912.

Bell, Robert N.

64. Thirteenth annual report of the mining industry of Idaho for the year 1911, 135 pp., illust. [1912].

Includes notes on the occurrence and character of various ore bodies.

Bell, W. A.

65. Joggins Carboniferous section of Nova Scotia: Canada Geol. Survey, Summ. Rept., 1911, pp. 328–333, 1912.

Berkey, Charles P.

66. Prominent structure of the northern margin of the Highlands: Abstract, New York Acad. Sci., Annals, vol. 21, p. 210, 1912.

States results of recent studies in the Moodna Valley of southeastern New York.

Berry, Edward W.

67. Geology of the Virginia Coastal Plain; Lower Cretaceous: Virginia Geol. Survey, Bull. no. 4, pp. 61–86, 3 pls., 1 fig., 1912.

68. American Triassic Neocalamites: Bot. Gazette, vol. 53, no. 2, pp. 174–180, 1 pl., 1 fig., February, 1912.

Describes *Neocalamites knowltoni* n. sp. from the Richmond coal field of Virginia.

69. Notes on the genus Widdringtonites: Torrey Bot. Club, Bull., vol. 39, no. 7, pp. 341–347, 2 pls., 1 fig., July, 1912.

70. Contributions to the Mesozoic flora of the Atlantic Coastal Plain; VIII, Texas: Torrey Bot. Club, Bull., vol. 39, no. 8, pp. 387–406, 3 pls., August, 1912.

71. Pleistocene plants from the Blue Ridge in Virginia: Am. Jour. Sci., 4th ser., vol., 34, pp. 218–223, 5 figs., August, 1912.

72. The age of the plant-bearing shales of the Richmond coal field: Am. Jour. Sci., 4th ser., vol. 34, pp. 224–225, August, 1912.

73. Notes on the geological history of the walnuts and hickories: Plant World, vol. 15, no. 10, pp. 225–240, 4 figs., October, 1912.

The physiography and geology of the Coastal Plain province of Virginia. Lower Cretaceous. See Clark and Miller, no. 192.

Biolley, Pablo.

Informe sobre el terremoto de Toro Amarillo, Grecia. See Alfaro, Michaud, and Biolley, no. 8.

Registro de temblores, 1911. See Tristan and Biolley, no. 1102.

The Sarchi earthquake, Costa Rica. See Tristan and others, no. 1103.

Birge, Edward A.

74. Report of the director of the Survey: Wisconsin Geol. and Nat. Hist. Survey. Eighth Bienn. Rept., 1910–1912, 39 pp., 1912.

An administrative report giving a review of the operations of the survey.

Bishop, Watson L.

75. R[obert] W[heelock] Ells [1845–1911]: Nova Scotian Inst. Sci., Proc. and Trans., vol. 13, pt. 2, pp. xxv–xxvi., August 26, 1912.

Blackwelder, Eliot.

76. United States of America: Handbuch der Regionalen Geologie (Steinmann and Wilckens), Bd. 8, Abt. 2 (Heft 11), 258 pp., 81 figs., Heidelberg, 1912.

A comprehensive general account of the geology of the United States. Includes sections on the morphology (physiographic features), stratigraphy and formations, outline of the geologic history, the orographic elements, the economic geology, and summary of the literature, and a list of the formation names given in the text.

77. The old erosion surface in Idaho; a criticism: Jour. Geology, vol. 20, no. 5, pp. 410–414, July–August, 1912.

78. The Gros Ventre slide, an active earth flow: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 487–492, 5 pls., 2 figs., October 21, 1912. Abstract: Geol. Soc. America, Bull., vol. 23, no. 4, p. 739, December 17, 1912.

Describes a landslide in western Wyoming south of Yellowstone National Park characterized by continuous slow motion for several years.

Blatchley, Raymond S.

79. Oil investigations in Illinois: Illinois Acad. Sci., Trans., vol. 4, pp. 85–97, 6 pls. (maps and sections), 1912.

Includes sections in different parts of the state.

80. The structural relations of the oil fields of Crawford and Lawrence counties, Illinois: Econ. Geology, vol. 7, no. 6, pp. 574–582, 3 pls. (map and sections), September, 1912.

81. The Illinois petroleum fields: Am. Geog. Soc., Bull., vol. 44, no. 6, pp. 417–426, map, June, 1912.

82. Illinois oil industry, its history and development: Min. and Eng. World, vol. 36, pp. 1293–1295, 1 fig., June 22, 1912.

83. Structure of the principal oil fields of Illinois: Min. and Eng. World, vol. 37, pp. 1098–1099, 1 fig. (map), December 14, 1912.

Bleininger, A. V., **Lines**, E. F., and **Layman**, F. E.

84. Portland-cement resources of Illinois: Illinois State Geol. Survey, Bull. no. 17, 121 pp., 19 pls., 1912.

Böggild, O. B.

85. Krystalform og tvillingdannelser hos kryolit, perovskit, og boracit: Meddelelser om Groenland, Bd. 50, pp. 1–95, 2 pls., 32 figs., 1912; Zeits. Krystal., Bd. 50, H. 4–5, pp. 349–429, 2 pls., 32 figs., 1912.

Describes the crystallography of cryolite, perovskite, and boracite.

86. Iagttagelser over kryolitgruppens mineraler: Meddelelser om Groenland, Bd. 50, pp. 105–129, 1 pl., 6 figs., 1912; Zeits. Krystal., Bd. 51, H. 6, pp. 591–613, 1 pl., 6 figs., 1912.

Describes minerals belonging to the cryolite group.

87. De stalaktitiske mineraler fra Ivigtut: Meddelelser om Groenland, Bd. 50, pp. 175–185, 1 pl., 1912; Zeits. Krystal., Bd. 51, H. 6, pp. 614–623, 1 pl., 1912.

Describes stalactitic minerals from Ivigtut, Greenland.

88. Ueber die Krystallform des Britholiths: Zeits. Krystal., Bd. 50, H. 4–5, pp. 430–436, 2 figs., 1912.

Describes the crystallography of britholite from Greenland.

Böhm, Joh.

89. Literarische Bemerkung über *Porocystis pruniformis* Cragin: Centralbl. Mineralogie, no. 3, pp. 86–87, February 1, 1912.

A note stating that *Porocystis pruniformis* Cragin from the Cretaceous of Texas is a synonym for *Porocystis globularis* Giebel sp.

Boileau, John W.

90. Coal fields of southwestern Pennsylvania, Washington, and Greene counties. 90 pp., maps and illustrations. [Private publication], copyright, 1907.

Includes an account of the stratigraphy and geologic structure.

Booth, William M.

The Ontario iron mine, New York. See Taylor and Booth, no. 1070.

Bosworth, T. O.

91. Birth of an island near the coast of Trinidad: Geol. Mag., dec. 5, vol. 9, no. 4, pp. 159–163, 1 fig. (map), April, 1912.

Boutwell, John Mason.

92. Geology and ore deposits of the Park City district, Utah, with contributions by Lester Hood Woolsey: U. S. Geol. Survey, Prof. Paper 77, 231 pp., 44 pls., 18 figs., 1912.

Bowen, C. F.

93. The Baker lignite field, Custer County, Montana: U. S. Geol. Survey, Bull. 471, pp. 202–226, 2 pls. (map and sections), 1912.

Bowen, N. L.

94. The composition of nephelite: Am. Jour. Sci., 4th ser., vol. 33, pp. 49–54, 1 fig., January, 1912.

95. The binary system; $Na_2Al_2Si_2O_8$ (nephelite, carnegieite)—$CaAl_2Si_2O_8$) (anorthite): Am. Jour. Sci., 4th ser., vol. 33, pp. 551–573, 2 diagrams., June, 1912.

96. The order of crystallization in igneous rocks: Jour. Geology, vol. 20, no. 5, pp. 457–468, 6 figs., July–August, 1912.

Bowie, William.

97. Effect of topography and isostatic compensation upon the intensity of gravity (second paper): U. S. Coast and Geodetic Survey, Special Publication no. 12, 28 pp., 5 pls. (in pocket), 1912.

98. Some relations between gravity anomalies and the geologic formations in the United States: Am. Jour. Sci., 4th ser., vol. 33, pp. 237–240, March, 1912.

99. Some relations between gravity anomalies and the geologic formation in the United States: Abstract, Science, new ser., vol. 35, p. 320, February 23, 1912.

100. Some results of the Hayford method of gravity reduction: Washington Acad. Sci., Jour., vol. 2, no. 21, pp. 499–504, December 19, 1912.

The effect of topography and isostatic compensation upon the intensity of gravity. See Hayford and Bowie, no. 441.

Bowles, Oliver.

101. Crystallographic tables: Science, new ser., vol. 35, pp. 576–577, April 12, 1912.

Bownocker, J. A.

Geology of the Columbus quadrangle. See Stauffer and others, no. 1025.

Bradley, W. M.

On solid solution in minerals; II, The chemical composition of analcite. See Foote and Bradley, no. 331.

The chemical composition of nephelite. See Foote and Bradley, no. 332.

Pseudomorphs after stibnite from San Luis Potosi, Mexico. See Ford and Bradley, no. 338.

Branner, J. C.

102. An early discovery of fuller's earth in Arkansas: Am. Inst. Min. Eng., Bull., no. 67, pp. 747–749, July, 1912; Trans., vol. 43, pp. 520–522, 1913.

Branson, E. B.

103. A Mississippian delta (with discussion by J. M. Clarke, David White, G. W. Stose, Arthur Keith, E. T. Wherry, and H. B. Kümmel, on pp. 744–746): Geol. Soc. America, Bull., vol. 23, no. 3, pp. 447–456, 2 figs., September 25, 1912; Abstract, Science, new ser., vol. 35, p. 317, February 23, 1912.

Describes Mississippian deposits in northern Virginia and presents an interpretation of the conditions of sedimentation.

The Cenozoic history of the Wind River Mountains, Wyoming. See Westgate and Branson, no. 1184.

Breger, Carpel L.

104. Potash in the United States and foreign countries: Min. and Eng. World, vol. 36, pp. 297–298, February 3, 1912.

105. Index to the world's current oil literature: Min. and Eng. World, vol. 36, pp. 1310–1316, June 22, 1912.

Brewer, W. M.

106. Mineral resources of the Kenai Peninsula [Alaska]: Min. and Sci. Press, vol. 105, p. 662, November 23, 1912.

British Columbia.

Annual report of the minister of mines for the year ending 31st December, 1911, being an account of mining operations for gold, coal, etc., in the Province of British Columbia. Victoria, B. C., 1912. See Robertson, no. 920.

Brock, Reginald Walter.

107. Summary report of the Geological Survey Branch of the Department of Mines [of Canada] for the calendar year 1911. 412 pp., 11 pls. (incl. maps), 7 figs. Ottawa, 1912.

Outlines the administrative work and field investigations carried on in 1911. Includes reports by members of the staff.

108. Tin and topaz in New Brunswick: Min. Soc. Nova Scotia, Jour., vol. 17, pp. 50–54, 1912.

Brodie, W. S.

109. Some effects of ice action near Grand Lake, Cape Breton: Nova Scotian Inst. Sci., Proc. and Trans., vol. 12, pt. 3, pp. 253–257, 1 fig., March, 1912.

Describes low ridges roughly paralleling lake shores and discusses the mode of their formation.

Brooks, Alfred H.

110. Applied geology: Washington Acad. Sci., Jour., vol. 2, no. 2, pp. 19–48, 3 figs., January 10, 1912.

Presidential address delivered before the Geological Society of Washington, December 13, 1911.

111. Mineral resources of Alaska in 1911; administrative report: U. S. Geol. Survey, Bull. 520, pp. 7–16, 1912.

112. The mining industry [in Alaska] in 1911: U. S. Geol. Survey, Bull. 520, pp. 17–44, 1 pl. (map), 1912.

113. Railway routes from the Pacific seaboard to Fairbanks [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 45–88, 3 pls. (maps), 1912.

114. Gold deposits near Valdez [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 108–130, 1 pl. (map), 1912.

Includes notes on the stratigraphy and geologic structure of the region.

Mineral resources of the United States, 1911: Gold, silver, copper, lead, and zinc in Alaska. See no. 115.

The New Madrid earthquake: Abstract. See Fuller, no. 344.

Brooks, Alfred H., and others.

115. Mineral resources of Alaska; report on progress of investigations in 1911: U. S. Geol. Survey, Bull. 520, 360 pp., 15 pls. (chiefly maps), 1912.

Brown, Amos P.

116. The formation of ripple marks, tracks, and trails: Acad. Nat. Sci. Philadelphia, Proc., vol. 63, pt. 3, pp. 536–547, 2 pls., 4 figs., 1912.

Brown, Amos P., and **Pilsbry,** H. A.

117. Note on a collection of fossils from Wilmington, North Carolina: Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pp. 152–153, 1 pl., 1912.

Brown, Barnum.

118. A discovery in the fossil fields of Mexico: Am. Mus. Jour., vol. 12, no. 5, pp. 177–180, 5 figs., May, 1912.

Describes the discovery of a specimen of glyptodont in the State of Jalisco, Mexico.

119. The osteology of the manus in the family Trachodontidæ: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 105–108, 2 figs., 1912.

120. A crested dinosaur from the Edmonton Cretaceous: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 131–136, 2 pls., 4 figs., 1912.

Describes *Saurolophus osborni* new gen. and sp.

121. Brachyostracon, a new genus of Glyptodonts from Mexico: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 167–177, 6 pls., 4 figs., 1912.

Brown, Thomas A.

122. The placer mines of Summit County, Colorado, and geological structure thereof: Min. Science, vol. 65, p. 171, February 15, 1912.

Bruce, E. L.

123. The Swastika gold area: Ontario, Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 256–265, 9 figs., 1912.

Describes the geology of the area, pre-Cambrian rocks, and the occurence of gold.

124. Cripple Creek gold area [Ontario]: Ontario, Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 266–270, 2 figs., 1912.

Gives notes on the geology of the area.

Bryant, J. W.

125. A new copper district: Min. Mag., vol. 7, no. 6, pp. 448–449, 2 figs., December, 1912.

Includes notes on the geology and copper ores of the Klehini Valley, British Columbia.

Buckman, S. S.

126. A method of removing tests from fossils: Am. Jour. Sci., 4th ser., vol. 33, pp. 593–594, June, 1912.

Buehler, H. A.

Oxidation of sulphides (second paper). See Gottschalk and Buehler, no. 384.

Bugge, Carl.

127. Petrographische Resultate der 2ten Fram-Expedition: Norwegian Arctic Expedition in the "Fram" (Second), Rept., no. 22, 38 pp., 9 pls., 1 fig. (published by Videnskabs-Selskabet i Kristiania), 1910.

Describes petrographic characters of igneous rocks of pre-Cambrian age in Ellesmere Land.

Burbank, J. E.

128. One phase of microseismic motion: Am. Jour. Sci., 4th ser., vol. 33, pp. 470–473, May, 1912.

129. Microseisms caused by frost action: Am. Jour. Sci., 4th ser., vol. 33, pp. 474–475, May, 1912.

Burchard, Ernest F.

130. Granite, marbles, and other building stones of the South: Manufacturers Record, vol. 61, no. 7, pt. 2, pp. 59–60, February 22, 1912.

131. Methods of preparation of sand and descriptions of deposits: U. S. Geol. Survey, Min. Res. U. S. 1911, pt. 2, pp. 596–622, 1912.

132. Stone resources east of Mississippi River: U. S. Geol. Survey, Min. Res. U. S. 1911, pt. 2, pp. 782–831, 7 pls. (maps), 1912.

Mineral resources of the United States, 1911: Iron ore, pig iron and steel; manganese and manganiferous ores; cement industry in the U. S. in 1911; glass sand, other sand, and gravel; gypsum; lime; stone; fluorspar and cryolite. See no. 1127.

Burckhardt, Carlos.

133. Faunes jurassiques et crétaciques de San Pédro del Gallo [l'état de Durango, Mexico]: Mexico, Inst. Geol., Bol., no. 29, 260 pp., and atlas of 46 pls., 1912.

Describes the stratigraphy of the vicinity of San Pedro del Gallo, State of Durango, Mexico, and gives systematic descriptions of the Jurassic and Cretaceous fossils, chiefly Cephalopoda.

Burling, Lancaster D.

134. A key to basin-range structure in the Cricket Range, Utah: Science, new ser., vol. 36, p. 240, August 23, 1912.

135. [The relations of the Sherbrooke formation to the Ordovician in British Columbia]: Washington Acad. Sci., Jour., vol. 2, no. 14, p. 357, August 19, 1912.

136. The nomenclature of types: Washington Acad. Sci., Jour., vol. 2, no. 21, pp. 519–520, December 19, 1912.

Burrows, A. G.

137. The Porcupine gold area (second report): Ontario, Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 205–249, 37 figs., 1912.

Describes the geology of the area, pre-Cambrian rocks, and the character and relations of the gold-bearing deposits.

The Porcupine gold area of northern Ontario: Canadian Min. Inst., Jour., vol. 14, pp. 203–206, 1912. See no. 175 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 23.

Bustamante, M.

138. Observaciones sobre la edad relativa de dos sistemas de vetas que se cortan; consideraciones sobre la formación de los sàltos y experiencias para producir en losetas grietas que simulan perfectamente los saltos que se observan en las vetas: Inst. Mexicano de Minas y Metal., Informes y Memorias, Año 2, no. 6, pp. 222–230, 1910–1911.

Discusses the relative age of two intersecting systems of veins and experiments made in elucidating the views advanced.

Butler, B. S.

139. The Morenci-Metcalf district [Arizona]: Min. Science, vol. 65, p. 154, February 8, 1912.

140. Geological classification of copper deposits: U. S. Geol. Survey, Min. Res. U. S., 1911, pt. 1, pp. 257–262, 1912.

Geology and mineralization in the Tushar Range. See Butler and Gale, no. 141.

Mineral resources of the United States, 1911: Copper. See no. 1127.

Butler, B. S., and **Gale,** H. S.

141. Alunite; a newly discovered deposit near Marysvale, Utah: U. S. Geol. Survey, Bull. 511, 64 pp., 3 pls., 1912; abstract, Washington Acad. Sci., Jour., vol. 2, no. 7, p. 193, April 4, 1912.

Describes the occurrence, extent, and geologic relations of the alunite vein, the geology and mineralization of the Tushar Range, in which the vein is found, other known occurrences of alunite in the United States, and some foreign deposits, and discusses the origin of the Marysvale alunite deposit.

Butler, B. S., and **Schaller,** W. T.

142. Einige Mineralien von Beaver Co., Utah: Zeits. Krystal., Bd. 50, H. 2, pp. 114–119, 1 fig., 1912.

Translation of a paper published in the American Jour. of Science, 4th ser., vol. 32, pp. 418–424, December, 1911. See the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 23, entry 179.

Butler, G. Montague.

143. Recent developments in geology: Colorado School of Mines Mag., vol. 2, no. 5, pp. 93–95, 115–117, February, 1912.

144. Some recent developments at Leadville [Colorado]; a Leadville fissure vein: Econ. Geology, vol. 7, no. 4, pp. 315–323, 1 fig., June, 1912.

Describes the occurrence and character of the vein and the mineralization and discusses the genesis of the ores.

145. Some recent developments at Leadville; a Leadville fissure vein: Colorado School of Mines, Quart., vol. 8, no. 1, pp. 1–8, 1 fig., April, 1913

146. Some recent developments in geology: Min. Science, vol. 65, pp. 213–214, February 29, 1912.

147. The gold of Newlin's Gulch, near Denver, Colorado; preliminary report upon an alluvial deposit apparently derived from an ancient placer: Min. Science, vol. 65, pp. 486–487, 2 figs., June 6, 1912.

Geology and ore deposits of the Alma district, Park County, Colorado. See Patton and others, no. 834.

Butts, Charles.

148. New dolomite formations in Alabama: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 9, p. 231, May 4, 1912.

Cairnes, DeLorme D.

149. Wheaton district, Yukon Territory: Canada Geol. Survey, Mem. no. 31, x, 153 pp., 14 pls., 10 figs., 4 maps, 1912.

Describes the general physical features of the district, the general geology, the occurrence, character, and lithology of formations ranging in age from Paleozoic to Quaternary, the geologic structure and history, and the ore deposits, containing gold, silver, antimony, and lead.

150. Geology of a portion of the Yukon-Alaska boundary between Porcupine and Yukon rivers: Canada Geol. Survey, Summ. Rept., 1911, pp. 17–33, 1 pl. (map), 1912.

151. Quartz mining in the Klondike district: Canada Geol. Survey, Summ. Rept., 1911, pp. 33–40, 1912.

Includes notes on the occurrence, character, and gold content of quartz veins.

152. Some suggested new physiographic terms: Am. Jour. Sci., 4th ser., vol. 34, pp. 75–87, 3 figs., July, 1912.

Defines the terms equiplanation, deplanation, and applanation, explains their purpose, and illustrates their use.

Cairnes, DeLorme D.—Continued.

153. Differential erosion and equiplanation in portions of Yukon and Alaska: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 333–348, 4 pls., 1 fig., July 15, 1912; Abstract, Science, new ser., vol. 35, p. 318, February 23, 1912.

154. Banded slates of the Orange group: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 424–425, September, 12, 1912.

Describes the occurrence and character, particularly the color banding, of the Orange beds along the Alaska-Yukon international boundary.

155. The ore and coal-bearing formation of the Yukon: Canadian Min. Jour., vol. 33, pp. 407–408, June 15, 1912.

Canadian tellurium-containing ores: Canadian Min. Inst., Jour., vol. 14, pp. 185–202, 2 pls., 1 fig., 1912. See no. 189 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 24.

California State Mining Bureau.

156. Report of the Board of Trustees and state mineralogist covering the sixtieth fiscal year ending June 30, 1909, and sixty-first fiscal year ending June 30, 1910. 29 pp. Sacramento, 1910.

An administrative report.

Calvert, W. R.

157. Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey, Bull. 471, pp. 187–201, 1 fig. (map), 1912.

158. The Livingston and Trail Creek coal fields, Park, Gallatin, and Sweetgrass counties, Montana: U. S. Geol. Survey, Bull. 471, pp. 384–405, 1 pl. (map), 1912.

159. The electric coal field, Park County, Montana: U. S. Geol. Survey, Bull. 471, pp. 406–422, 1 pl. (map), 1912.

Cameron, Frank K., and others.

160. A preliminary report on the fertilizer resources of the United States: U. S., 62d Cong., 2d Sess., Sen. Doc. no. 190, 290 pp., 19 pls., 3 figs., 19 maps, 1912.

Campbell, Marius R.

161. Contributions to economic geology (short papers and preliminary reports), 1910; Part II, Mineral fuels: U. S. Geol. Survey, Bull. 471, 663 pp., 62 pls., 15 figs., 1912.

Camsell, Charles.

162. Fraser Canyon and vicinity: Canada Geol. Survey, Summ. Rept., 1911, pp. 108–111, 1912.

163. Geology of a portion of Lillooet mining division, Yale district, British Columbia: Canada Geol. Survey, Summ. Rept., 1911, pp. 111–115, 1 pl. (map), 1912.

164. Geology of Skagit Valley, Yale District, B. C.: Canada Geol. Survey, Summ. Rept., 1911, pp. 115–123, 1912.

165. Note on the occurrence of diamonds at Tulameen and Scottie Creek, near Ashcroft, B. C.: Canada Geol. Survey, Summ. Rept., 1911, pp. 123–124, 1912.

The mineral resources of a part of the Yale district, B. C.; a descriptive summary: Canadian Min. Inst., Jour., vol. 14, pp. 596–611, 1912. See no. 193 of the bibliography for 1910, U. S. Geol. Survey, Bull. 495, p. 25.

Canada, Department of Mines, Mines Branch.

166. Summary report of the Mines branch of the Department of Mines for the calendar year ending December 31, 1911. 208 pp., 16 pls., 6 figs., 1 map. Ottawa, 1912.

Canada, Geological Survey.

167. [Geological map of] Province of Nova Scotia, Kings County, Hall Harbour sheet, no. 99: Canada, Geol. Survey, Pub. no. 1134. Scale 1 mile to 1 inch. 1910.

168. [Geological map of] Province of Nova Scotia, Hants and Kings counties, Kingsport sheet no. 84: Canada, Geol. Survey, Pub. 1133. Scale 1 mile to 1 inch. 1911.

169. [Geological map of Canada]: Canada, Geol. Survey, Pub. no. 1084 (to accompany publications nos. 1085 and 1086). Scale 1:6 336 000 [1912.]

Cantley, Thomas.

The Wabana iron mines of the Nova Scotia Steel and Coal Company Limited: Canadian Min. Inst., Jour., vol 14, pp. 274–298, 7 pls., 2 figs., 1912. See no. 209 of the bibliography for 1911, U. S. Geol. Survey. Bull. 524, p. 25.

Capps, Stephen R.

170. The Bonnifield region, Alaska: U. S. Geol. Survey, Bull. 501, 64 pp., 8 pls. (incl. maps), 3 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 13, p. 326, July 19, 1912.

Describes the general character of the region, the occurrence, character, and relations of Paleozoic, Tertiary, and Quaternary deposits, and the mineral resources, gold and coal.

171. Gold placers of the Yentna district [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 174–200, 2 pls. (maps), 1912.

Includes notes on the stratigraphy of the region.

172. Glaciation of the Alaska Range: Jour. Geology. vol. 20, no. 5, pp. 415–437, 1 pl., 10 figs., July–August, 1912.

Carman, J. Ernest.

173. A grooved and striated contact plane between the Nebraskan and Kansan drifts: Abstract, Science, new ser., vol. 35, p. 316, February 23, 1912; Abstract (with discussion by Frank Leverett), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 735–736, December 17, 1912.

174. The Nebraskan drift of the Little Sioux Valley in northwest Iowa: Abstracts, Science, new ser., vol. 35, p. 316, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 735, December 17, 1912.

Case, E. C.

175. A revision of the Cotylosauria of North America. 122 pp., 14 pls., 52 figs. Washington, D. C., published by the Carnegie Institution of Washington (Pub. no. 145), 1911.

176. Ten years' progress in vertebrate paleontology; Paleozoic Reptilia and Amphibia: Geol. Soc. America, Bull., vol. 23. no. 2, pp. 200–204, June 1, 1912.

The Permo-Carboniferous of northern New Mexico. See Williston and Case, no 1216.

Case, E. C., and **Williston,** S. W.

177. A description of the skulls of *Diadectes lentus* and *Animasaurus carinatus:* Am. Jour. Sci., 4th ser., vol. 33, pp. 339–348, 3 figs., April, 1912.

Chadwick, George Halcott.

178. Color scheme for crystal models (abstract): Geol. Soc. America, Bull., vol. 23, no. 4, p. 728, December 17, 1912.

Chamberlin, Thomas Chrowder.

179. The bearings of radioactivity on geology: Illinois Acad. Sci., Trans., vol. 4, pp. 57–75, 1912.

Chapman, Temple.

180. The Miami zinc-lead district, Oklahoma: Eng. and Min. Jour., vol. 93, pp. 1146–1147, June 8, 1912.

Cirkel, Fritz.

181. The Amherst graphite deposits in Quebec: Min. and Eng. World, vol. 36, pp. 295–296, February 3, 1912.

Clapp, Charles H.

182. Southern Vancouver Island: Canada Geol. Survey, Mem. no. 13, 208 pp., 18 pls., 3 figs., geol. map, 1912.

Describes the physiography and general geology, the occurrence, character, and relations of Carboniferous, Jurassic, Cretaceous, and Tertiary rocks, and the mineral resources, chiefly gold, copper, and coal.

183. Geology of the Nanaimo sheet, Nanaimo coal field, Vancouver Island, British Columbia: Canada Geol. Survey, Summ. Rept. 1911, pp. 91–105, 1 pl. (map), 1912.

184. Notes on the geology of the Comox and Suquash coal fields, Vancouver Island: Canada Geol. Survey, Summ. Rept., 1911, pp. 105–107, 1912.

Clapp, Charles H., and **Allan**, J. A.

185. Southern Vancouver Island, British Columbia: Canada Geol. Survey, Map 17A (to accompany Mem. no. 13), 1911. Scale, 1:380,160.

Clapp, Frederick G.

186. The occurrence of oil and gas deposits associated with quaquaversal structure: Econ. Geology, vol. 7, no. 4, pp. 364–381, 6 figs., June 1912.

187. Occurrence of petroleum associated with faults and dikes: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 728, December 17, 1912.

The underground waters of southwestern Ohio. See Fuller and Clapp, no. 346.

Clark, Bruce L.

188. The Neocene section at Kirker Pass on the north side of Mount Diablo: California, Univ., Dept. Geology, Bull., vol. 7, no. 4, pp. 47–60, 1 pl., (map), October 10, 1912.

Clark, George Archibald.

189. The Katmai eruption: Seism. Soc. America, Bull., vol. 2, no. 4, pp. 226–229, 2 pls., December, 1912.

Includes data on the eruption of Katmai volcano in the vicinity of Kadiak Island, Alaska, in June, 1912.

Clark, Hubert Lyman.

190. Fossil holothurians: Science, new ser., vol. 35, pp. 274–278, February 16, 1912.

Presents considerations to show that the Cambrian fossils from British Columbia described by Walcott as holothurians can not be classed as holothurians or echinoderms.

Clark, William Bullock.

191. Report of the Maryland Geological Survey: Johns Hopkins Univ. Circular, 1912, no. 1, pp. 99–100, 1912.

The physiography of the Coastal Plain of North Carolina. See Clark and others, no. 193.

The correlation of the Coastal Plain formations of North Carolina. See Clark and others, no. 193.

Clark, William Bullock, and **Miller,** Benjamin Le Roy.

192. The physiography and geology of the Coastal Plain province of Virginia, with chapters on the Lower Cretaceous, by Edward W. Berry, and the economic geology, by Thomas Leonard Watson: Virginia Geol. Survey, Bull. no. 4, pp. 13–222, 16 pls., 1 fig., 1912.

Clark, William Bullock, and others.

193. The Coastal Plain of North Carolina: North Carolina Geol. and Econ. Survey, vol. 3, 552 pp., 42 pls., 21 figs., 2 geol. maps, 1912.

Includes the following sections:

The physiography of the Coastal Plain of North Carolina, by William Bullock Clark, pp. 23–33.

The stratigraphy of the Coastal Plain of North Carolina, by William Bullock Clark, B. L. Miller, and L. W. Stephenson, pp. 34–44.

Bibliography, by B. L. Miller and L. W. Stephenson, pp. 44–73.

The Cretaceous formations, by L. W. Stephenson, pp. 73–171.

The Tertiary formations, by Benjamin L. Miller, pp. 171–258.

Lafayette formations, by L. W. Stephenson, pp. 258–266.

Quaternary formations, by L. W. Stephenson, pp. 266–290.

The geological history of the Coastal Plain of North Carolina, by William Bullock Clark, Benjamin L. Miller, and L. W. Stephenson, pp. 291–303.

The correlation of the Coastal Plain formations of North Carolina, by William Bullock Clark, pp. 304–330.

Water resources of the Coastal Plain of North Carolina, by L. W. Stephenson and B. L. Johnson, pp. 333–483.

The quality of some waters of the Coastal Plain of North Carolina, by Horatio N. Parker, pp. 484–509.

Clark, R. W.

194. Heat conductivity of crystals: Science, new ser., vol. 36, p. 415, September 27, 1912.

Clarke, Frank Wigglesworth.

195. Some geochemical statistics: Am. Philos. Soc., Proc., vol. 51, pp. 214–234, July, 1912.

Discusses the average composition of igneous and sedimentary rocks and the character and magnitude of marine sedimentation.

196. Some geochemical statistics: Abstract, Science, new ser., vol. 35, p. 791, May 17, 1912.

197. An aluminum arsenate from Utah: Washington Acad. Sci., Jour., vol. 2, no. 21, pp. 516–518, December 19, 1912.

Clarke, John Mason.

198. Eighth report of the director of the science division, including the 65th report of the State Museum, the 31st report of the State geologist, and the report of the State paleontologist for 1911: New York State Museum, Bull. 158, pp. 5–50, 8 pls., 1912.

An administrative report, but includes data on the geology and paleontology of New York.

Clarke, John Mason—Continued.

199. Notes on the geology of the Gulf of St. Lawrence: New York State Mus., Bull. 158, pp. 111–126, 14 pls., 5 figs., 1912.

Describes the physiography and geology of Entry Island, one of the Magdalen Islands, in the Gulf of St. Lawrence; a Silurian section on the Bay of Chaleur; and an uncomformity at Little River East, Gaspe County, Quebec.

200. Early adaptation in the feeding habits of starfishes: Acad. Nat. Sci., Philadelphia, Jour., 2d ser., vol. 15, pp. 113–118, 3 pls., 1912.

Describes the association on slabs of Devonian sandstone near Saugerties, N. Y., of starfish with Grammysia and Pterinea and their probable predatory habits.

A Mississippian delta. See Branson, no. 103.

Clarke, John M., and **Ruedemann**, Rudolf.

201. The Eurypterida of New York: New York State Mus., Mem. 14, vol. 1 (text), 439 pp., 1 pl., 121 figs., vol. 2 (plates), pp. 441–628, 88 pls., 1912.

Cleland, Herdman F.

202. Twelfth annual intercollegiate excursion of New England: Science, new ser., vol. 36, pp. 508–509, October. 1912.

Includes notes on the geology of the region from Westfield to Meriden, Conn.

203. The New England geological excursion: Science, new ser., vol. 36, pp. 624–625, November 8, 1912.

Clem, Harry M.

204. Laboratory work in physiography in the Chicago high schools: Jour. Geog., vol. 10, no. 9, pp. 290–295, May, 1912.

Clifford, James O.

205. Interesting review of Chino's mines and methods: Mines and Methods, vol. 3, no. 12, pp. 547–552, 3 figs., August, 1912.

Includes notes on the local geography and the occurrence and character of the copper ores at Santa Rita, Grant County, New Mexico.

206. Ray Consolidated properties; description and comment: Mines and Methods, vol. 4, no. 4, pp. 83–89, 5 figs., December, 1912.

Gives notes on the local geology and the character and occurrence of copper ores at Ray, Pinal County, Arizona.

Cockerell, T. D. A.

207. Scudder's work on fossil insects: Psyche, vol. 18, no. 6, pp. 181–186, December, 1911.

208. The Miocene fauna of Florissant, Colorado: Abstract, Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 745–747, Cambridge, U. S. A., 1912.

Describes specimens of insects recently found in the Miocene shales of Florissant, Colo.

209. Fossil fruits and flowers, II: Torreya, vol. 12, no. 2, pp. 32–33, 1 fig., February, 1912.

Describes *Robinia mesozica* n. sp., from the Laramie of Whitely Peak, Colo.

210. The oldest American homopterous insect: Canadian Entomologist, vol. 44, no. 3, pp. 93–95, 1 fig., March, 1912.

Describes *Petropteron mirandum* n. gen. and n. sp. from the Pierre formation at Boulder, Colo.

Cockerell, T. D. A.—Continued.

211. A fossil Raphidia [from the Miocene shales of Florissant, Colo.]: Entomological News, vol. 23, no. 5, pp. 215–216, 1 fig., May, 1912.

212. Fossil cockroaches from Texas (Orthop.): Entomological News, vol. 23, no. 5, pp. 228–229, May, 1912.

Gives the type locality from which *Ettoblattina texana* and *E.* (?) *robusta* Sellards were obtained.

Cockerell, T. D. A., and Henderson, Junius.

213. Mollusca from the Tertiary strata of the West: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 229–234, 2 pls., 1912.

Coghill, Will H.

214. A peculiar occurrence of silver (discussion): Econ. Geology, vol. 7, no. 8, pp. 783–785, 1 fig., December, 1912.

Cole, L. H.

215. The gypsum and salt industries of central and western Canada: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 108–116, 1912.

Coleman, A. P.

216. Summary report on the Sudbury nickel field: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 87–89, 1912.

Collins, George E.

217. Persistence of ore in depth: Min. and Sci. Press, vol. 105, pp. 409–410, September 28, 1912.

Collins, W. H.

218. Geology of Onaping sheet, Ontario, portion of map area between West Shiningtree and Onaping lakes: Canada Geol. Survey, Summ. Rept., 1911, pp. 244–252, 1 pl. (map), 1912.

Collister, M. C.

The terranes of Albany, Vermont. See Richardson and Collister, no. 904.

Commission Minière de Chibougamau.

Rapport sur la géologie et les ressources minières de la région de Chibougamau, Québec: Québec (Province), Ministere de la Colonisation, des Mines, et des Pêcheries, Bureau des Mines. 243 pp., 73 pls., 19 figs., 2 geol. maps, 1912. See Barlow and others, no. 64 of the bibliography for 1911, U. S. Geological Survey, Bull. 524, p. 15.

Condit, D. Dale.

219. The petrographic character of Ohio sands with relation to their origin: Jour. Geology, vol. 20, no. 2, pp. 152–163, February–March, 1912.

220. The sands of Ohio: Abstract, New York Acad. Sci., Annals, vol. 21, p. 210, 1912.

Discusses the distinguishing of sands by their characteristics.

Connecticut Geological and Natural History Survey Commission.

221. Fifth biennial report of the commissioners of the State geological and natural history survey of Connecticut. 12 pp. Hartford, 1912.

An administrative report.

Conner, Eli T.

Mining conditions under the City of Scranton, Pa. See Griffith and Conner, no. 404.

Conway, E. F.

The terranes of Irasburg, Vermont. See Richardson and Conway, no. 906.

Cook, Chas. W.

The salt industry of Michigan; Michigan cement. See Allen and others, no. 13.

Cook, Harold James.

222. A new genus and species of rhinoceros, *Epiaphelops virgasectus*, from the lower Miocene of Nebraska: Nebraska Geol. Survey, vol. 7, part 3, pp. 21–22, 1 pl., June, 1912.

223. A new species of rhinoceros, *Diceratherium loomisi*, from the lower Miocene of Nebraska: Nebraska Geol. Survey, vol. 7, part 4, pp. 29–32, 3 figs., August, 1912.

224. Faunal lists of the Tertiary formations of Sioux County, Nebraska: Nebraska Geol. Survey, vol. 7, part 5, pp. 33–45, August, 1912.

Gives lists by formations of the fossil Tertiary mammals found in Sioux County, Nebr.

225. Notice of a new genus of rhinoceros from the lower Miocene: Science, new ser., vol. 35, pp. 219–220, February 9, 1912.

Describes *Epiaphelops virgasectus* n. gen. and sp. from the Miocene beds of western Nebraska.

Cooper, H. C.

Die optischen Eigenschaften einiger Bleisilikate. See Kraus and others, no. 610.

Cornish, Vaughan.

226. On the cause of the Jamaica earthquake of January 14, 1907: Geog. Jour., vol. 40, no. 3, pp. 299–303, 1 fig. (map), September, 1912.

Coste, Eugene.

227. Fallacies in the theory of the organic origin of petroleums [with discussion by various writers]: Inst. Min. and Metall., Trans., vol. 21, pp. 91–192, 1912.

Cots, Cesar.

The Sarchi earthquake, Costa Rica. See Tristan and others, no. 1103.

Coulter, John M.

228. The history of gymnosperms: Pop. Sci. Monthly, vol. 80, no. 2, pp. 197–203, 1 fig., February, 1912.

229. The relations of paleobotany to botany; phylogeny and taxonomy: Am. Nat., vol. 46, pp. 215–225, April, 1912; Abstract, Science, new ser., vol. 35, pp. 148–149, January 26, 1912.

Cox, G. H.

230. New type of Wisconsin zinc deposit: Eng. and Min. Jour., vol. 94, pp. 1040–1041, 1 fig., November 30, 1912.

Cox, Jennings S., jr.

The iron-ore deposits of the Moa district, Oriente Province, Island of Cuba: Am. Inst. Min. Eng., Trans., vol. 42, pp. 73–90, 1912. See no. 285 of the bibliography for 1911, U. S. Geol. Survey, Bull 524.

Cox, N. H.

Roads and road materials of Florida. See Sellards and others, no. 964.

Crandall, Albert R.

231. Coals of the Licking Valley region and of some contiguous territory, including also an account of Elliott County and its dikes: Kentucky Geol. Survey, Bull. no. 10, 90 pp., 17 pls. (maps and sections), 1910 [distributed 1912 or 1913].

Crandall, Albert R., and **Sullivan**, George M.

232. Report on the coal field adjacent to Pineville Gap in Bell and Knox counties: Kentucky Geol. Survey, Bull. no. 14, 130 pp., 15 pls. (maps), 84 figs., 1912.

Crane, G. W.

233. The iron ores of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 10, xvi, 434 pp., 48 pls., 29 figs. [1912].

Describes the kinds, distribution, mode of occurrence, and geologic relations of the iron ores of Missouri, the physiography and geology of the iron-bearing region, and in detail, by counties, the occurrence and mining developments.

Crenshaw, J. L.

The sulphides of zinc, cadmium, and mercury; their crystalline forms and genetic conditions. See Allen and Crenshaw, no. 11.

The mineral sulphides of iron. See Allen, Crenshaw, and Johnston, no. 12.

Crook, A. R.

234. Geology of Sangamon County [Illinois]. 24 pp., 12 figs. Springfield, Ill., Illinois State Journal Co., 1912.

Reprinted with some revision from Historical Encyclopedia of Illinois, vol. 2, pp. 814–822.

Crosby, W. O.

235. Dynamic relations and terminology of stratigraphic conformity and unconformity: Jour. Geology, vol. 20, no. 4, pp. 289–299, May–June, 1912.

Cross, Whitman.

236. Alunite deposits of Rosita Hills, Colorado: U. S. Geol. Survey, Bull. 511, pp. 38–43, 1912.

237. Petrographic description [of rocks of Apishapa quadrangle, Colorado]: U. S. Geol. Survey, Geol. Atlas U. S., Apishapa folio (no. 186), pp. 9–10, 1912.

238. Petrological abstracts and reviews: Jour. Geology, vol. 20, no. 4, pp. 362–372, May–June, 1912.

239. Use of symbols in expressing the quantitative classification of igneous rocks: Jour. Geology, vol. 20, no. 8, pp. 758–762, 1912.

Potash-bearing rocks of the Leucite Hills, Sweetwater County, Wyoming. See Schultz and Cross, no. 957.

Cross, Whitman, **Iddings**, J. P., **Pirsson**, L. V., **Washington**, H. S.

240. Modifications of the quantitative system of classification of igneous rocks: Jour. Geology, vol. 20, no. 6, pp. 550–561, 1912.

Culbertson, Glenn.

241. Observations having for their object the approximate determination of the time required for the erosion of Clifty and Butler ravines in Jefferson County, Indiana: Indiana Acad. Sci., Proc., 1911, pp. 169–170, 1912.

242. The occurrence of hand specimens of jointed structure in the New Albany shale: Indiana Acad. Sci., Proc., 1911, pp. 171–172, 1 pl., 1912.

Cumings, Edgâr R.

243. Development and systematic position of the monticuliporoids: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 357–370, 4 pls., July 29, 1912.

244. Geological conditions of municipal water supply in the driftless area of southern Indiana: Indiana Acad. Sci., Proc. 1911, pp. 111–146, 9 figs., 1912.

Cumings, E. R., and **Galloway**, J. J.

245. A note on the Batostomas of the Richmond series: Indiana Acad. Sci., Proc. 1911, pp. 147–167, 7 pls., 1912.

Cumings, Willard L., and **Miller**, Benjamin L.

Characteristics and origin of the brown iron ores of Camaguey and Moa, Cuba: Am. Inst. Min. Eng., Trans., vol. 42, pp. 116–137, 8 figs., 1912. See no. 292 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Cushing, H. P.

246. The age of the Cleveland shale of Ohio: Am. Jour. Sci., 4th ser., vol. 33, pp. 581–584, June, 1912.

Cutler, H. C.

247. Como, Nevada: Min. and Sci. Press, vol. 104, pp. 539–540, 2 figs., April 13, 1912.

Includes notes on the geology of the Palmyra mining district.

Dachnowski, Alfred.

248. Peat deposits of Ohio, their origin, formation, and uses: Ohio Geol. Survey, 4th ser., Bull. 16, 424 pp., 8 pls., 29 figs., 1 map, April, 1912.

Dailey, I. M.

249. Report of the eruption of Katmai volcano: Am. Geog. Soc., Bull., vol. 44, no. 9, pp. 641–644, 3 figs., September, 1912.

Dale, T. Nelson.

250. The commercial marbles of western Vermont: U. S. Geol. Survey, Bull. 521, 170 pp., 17 pls. (incl. maps), 25 fig., 1912.

251. The Ordovician outlier at Hyde Manor in Sudbury, Vermont: Am. Jour. Sci., 4th ser., vol. 33, pp. 97–102, 2 figs., February, 1912.

Dall, William Healey.

252. The Mollusk fauna of northwest America: Acad. Nat. Sci. Philadelphia, Jour., 2d ser., vol. 15, pp. 241–248, 1912.

Reviews the progress of knowledge of the Mollusca of northwest America. Includes references to the fossil forms.

253. New species of fossil shells from Panama and Costa Rica, collected by D. F. MacDonald: Smithsonian Misc. Coll., vol. 59, no. 2, 10 pp., March 2, 1912.

Daly, Reginald A.

254. Reconnaissance of the Shuswap lakes and vicinity (south central British Columbia): Canada Geol. Survey, Summ. Rept., 1911, pp. 165–174, 1912.

255. Pre-Cambrian formations in south central British Columbia: Abstract, Science, new ser., vol. 35, p. 311, February, 1912.

256. Pre-Cambrian formations in south central British Columbia: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 721, December 17, 1912.

Daly, Reginald A., **Miller,** W. G., and **Rice,** George S.

257. Report of the commission appointed to investigate Turtle Mountain, Frank, Alberta: Canada, Geological Survey, Mem. no. 27, 34 pp., 19 pls., 11 figs., 2 maps, 1912.

Includes an account of the geologic structure of the mountain.

Dana, E. S.

258. George Jarvis Brush [1831-1912]: Am. Jour. Sci., 4th ser., vol. 33, pp. 389-396, 1 pl. (port.), May, 1912.

Includes a list of his writings.

Daniels, Joseph.

259. The Roslyn, Washington, coal field: Coal Age, vol. 1, pp. 1064-1066, 6 figs., May 25, 1912.

Darton, Nelson Horatio.

260. Notes on sand for mine flushing in the Scranton region [Pennsylvania]: U. S. Bureau Mines, Bull. 25, pp. 72-75, 1912.

261. Sandstone pinnacles: Geologische Charakterbilder (H. Stille), Heft 11, 6 pls. and explanatory text, 1912. √

Gives reproductions of photographs, with descriptive text, of erosion forms in western Nebraska and Colorado.

262. Silica and lime deposition: Geologische Charakterbilder (H. Stille), Heft 12, 6 pls. and explanatory text, 1912.

Gives reproductions of photographs taken in Yellowstone National Park, Mono Lake, Cal., and Cataract Canyon, Ariz., illustrating sinter deposits.

263. Some features in the Grand Canyon of Colorado River: Abstract, Science, new ser., vol. 35, p. 310, February 23, 1912.

264. Some features in the Grand Canyon of the Colorado River: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 721, December 17, 1912.

265. Volcanic action in the Black Hills of South Dakota: Science, new ser., vol. 36, pp. 602-603, November 1, 1912.

Davis, Charles A.

266. Some coastal marshes south of Cape Cod: Abstract, Science, new ser., vol. 35, p. 319, February 23, 1912.

267. Some coastal marshes south of Cape Cod: Abstract (with discussion by J. B. Woodworth and A. W. Grabau), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 742-743, December 17, 1912.

Davis, Charles H.

268. The Los Burros mining district [California]: Min. and Sci. Press, vol. 104, pp. 696-698, 1 fig., May 18, 1912.

Includes notes on the local geology and the occurrence and character of gold lodes and placers.

Davis, John A.

269. The Little Powder River coal field, Campbell County, Wyoming: U. S. Geol. Survey, Bull. 471, pp. 423-440, 4 pls. (maps and sections), 1912.

Davis, N. B.

The character and possible origin of the green dolomites of New Ontario: Canadian Min. Inst., Jour., vol. 14, pp. 678-689, 3 pls., 1 fig., 1912. See no. 318 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 33.

Davis, William Morris.

270. Die erklärende Beschreibung der Landformen. xviii, 565 pp., 13 pls., 212 figs. Leipzig, B. G. Teubner, 1912.

A treatise on the genetic description of land forms.

271. Relation of geography to geology (annual address of the president): Geol. Soc. America, Bull., vol. 23, no. 1, pp. 93–124, March 21, 1912.

272. Notes on descriptions of land forms: Am. Geog. Soc., Bull., vol. 43, pp. 46–51, 190–194, 598–604, 679–684, 847–853, 1911; vol. 44, pp. 908–913, 1912.

273. Physical geography: American Year Book, 1911, pp. 598–599, 1912.

Reviews progress in physiographic lines during the year 1911.

Day, Arthur L.

274. Geophysical research: Nature, vol. 88, pp. 331–334, January 4, 1912.

Dean, Bashford.

275. Ten years' progress in vertebrate paleontology; Paleozoic fishes: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 224–228, June 1, 1912.

Dellenbaugh, F. S.

276. Cross cutting and retrograding of streambeds: Science, new ser., vol. 35, pp. 656–658, April 26, 1912.

Denis, Théo. C.

277. The coal fields of Canada: Canada, Dept. Mines, Mines Branch, An Investigation of the Coals of Canada, vol. 1, pt. 2, pp. 21–126, 37 pls., 1912.

278. Report on mining operations in the Province of Quebec during the year 1911: Quebec (Province), Dept. of Colonization, Mines and Fisheries, Mines Branch, 211 pp., 19 pls., 15 figs., 1912.

Denison, F. Napier.

Earthquakes, strains, and stresses in relation to mine explosions: Canadian Min. Inst., Jour., vol. 14, pp. 84–92, 1 fig., 1912. See no. 330 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 34.

Derby, Orville A.

279. Speculations regarding the genesis of the diamond, II: Jour. Geology, vol. 20, no. 5, pp. 451–456, 1 fig., July–August, 1912.

DeWolf, Frank W.

280. Illinois mining and state geological survey: Illinois Soc. Eng. and Surveyors, Twenty-seventh Ann. Rept., pp. 152–155, 1912.

281. State geological surveys: American Year Book, 1911, pp. 585–589, 1912.

Reviews changes in personnel of state geologists and the work of the state surveys during the year 1911.

Diller, J. S.

282. Geological history of Crater Lake, Crater Lake National Park, Oregon U. S., Dept. of the Interior, 31 pp., 27 figs., 1912.

283. Mines and prospects of southwestern Oregon: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, p. 110, February 19, 1912.

The types and modes of occurrence of asbestos in the United States: Canadian Min. Inst., Jour., vol. 14, pp. 92–106, 1912. See no. 336 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 34.

Mineral resources of the United States, 1911: Talc and soapstone. See no. 1127.

Dilworth, J. B.

284. The Black Mountain coal district, Kentucky: Am. Inst. Min. Eng., Bull., no. 62, pp. 149–176, 3 figs., February, 1912; Trans., vol. 43, pp. 129–156, 3 figs., 1913.

Dole, R. B.

A discussion of the chemical character of the underground waters of southwestern Ohio. See Fuller and Clapp, no. 346.

Douglas, James.

Earthquakes in mines: Canadian Min. Inst., Jour., vol. 14, pp. 75–83, 1912. See no. 343 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 34.

Dowling, D. B.

285. Geology of Roche Miette map area, Jasper Park, Alberta: Canada Geol. Survey, Summ. Rept., 1911, pp. 201–219, 1912.

286. Notes on coal occurrences and the progress of development work in Alberta and Saskatchewan: Canada Geol. Survey, Summ. Rept., 1911, pp. 219–224, 1912.

287. Canadian coal resources: Canadian Inst., Trans., vol. 9, pt. 2, pp. 99–106, May, 1912.

The undeveloped coal resources of Canada: Canadian Min. Inst., Jour., vol. 14, pp. 326–346, 1912. See no. 346 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 35.

Dresser, John A.

288. Reconnaissance along the National Transcontinental Railway in southern Quebec: Canada Geol. Survey, Mem. no. 35, 42 pp., 6 pls., 4 figs., geol. map, 1912.

On the slate industry in southern Quebec: Canadian Min. Inst., Jour., vol. 14, pp. 149–163, 2 pls., 1 fig., 1912. See no. 348 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 35.

Drysdale, C. W.

289. Franklin mining camp, West Kootenay, B. C.: Canada Geol. Survey, Summ. Rept., 1911, pp. 133–138, 1 pl. (map), 1912.

Dulieux, E.

290. Preliminary report on some iron deposits on the north shore of the River and Gulf of St. Lawrence: Quebec (Province), Mines Branch, Rept. on mining operations during 1911, pp. 71–134, 7 pls., 12 figs., 1912.

291. The magnetic sands of the north shore of the Gulf of St. Lawrence: Quebec (Province), Mines Branch, Rept. on mining operations during 1911, pp. 135–159, 1 pl., 4 figs., 1912.

292. The titaniferous ores and the magnetic sands on the north shore of the St. Lawrence: Canadian Min. Jour., vol. 33, pp. 450–451, 1 fig., July 1, 1912.

Dumble, E. T.

293. Notes on Tertiary deposits near Coalinga oil field [California] and their stratigraphic relations with the upper Cretaceous: Jour. Geology, vol. 20, no. 1, pp. 28–37, 1912.

294. Tertiary deposits of eastern Mexico: Science, new ser., vol. 35, pp. 906–908, June 7, 1912.

295. The occurrence of gold in the Eocene deposits of Texas: Am. Inst. Min. Eng., Bull. no. 70, pp. 1021–1024, October, 1912.

Duncan, Gordon S.

296. Contribution to the study of the pre-Cambrian rocks of the Harney Peak district of South Dakota: Am. Inst. Min. Eng., Bull. no. 67, pp. 751–762, 3 figs., July, 1912; Trans., vol. 43, pp. 207–218, 3 figs., 1913.

Dunlop, J. P.

Mineral resources of the United States, 1911: Silver, copper, lead, and zinc in Central States (mine production). See no. 1127.

Eakin, Henry M.

297. The Rampart and Hot Springs regions [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 271–286, 1 pl. (map), 1912.

Includes an account of the stratigraphy.

Eakle, Arthur S.

298. The minerals of Tonopah, Nevada: California, Univ., Dept. Geology, Bull., vol. 7, no. 1, pp. 1–20, 2 pls., May 17, 1912.

299. Neocolemanite, a variety of colemanite, and howlite from Lang, Los Angeles County, California: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 70, March 14, 1912.

300. Mineral associations at Tonopah, Nevada: Abstract, Geol. Soc. America, Bull., vol., 23, no. 1, p. 70, March 14, 1912.

Eastman, Charles R.

301. Ten years' progress in vertebrate paleontology; Mesozoic and Cenozoic fishes: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 228–232, June 1, 1912.

302. Paleontology: American Year Book, 1911, pp. 656–660, 1912.

Reviews progress in paleontology during the year 1911.

Eaton, H. N.

303. The geology of South Mountain at the junction of Berks, Lebanon, and Lancaster counties, Pennsylvania: Jour. Geology, vol. 20, no. 4, pp. 331–343, 2 figs., May-June, 1912.

Describes the occurrence, character, and relations of pre-Cambrian, Cambrian, Ordovician, and Triassic strata, and the structural conditions.

Eckel, Edwin C.

304. Building stones and clays: their origin, characters, and examination. xiv, 264 pp., 37 figs. New York, John Wiley & Sons, 1912.

305. Iron-ore reserves: Eng. Mag., vol. 43, nos. 5 and 6, pp. 665–674, 825–836, vol. 44, pp. 7–15, August-October, 1912.

Edmonson, J. B.

306. Soil survey of Morgan and Owen counties: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 83–134, 2 pls. (maps), 2 figs., 1912.

Ells, R. W.

307. Notes on fossils found in certain metamorphic rocks of southern New Brunswick: Roy. Soc. Canada, Proc. and Trans., 3d ser., vol. 5, sec. 4, pp. 17–24, 1912.

Indicates fossil evidence by which the Devonian and Silurian age has been determined of some metamorphic formations formerly considered pre-Cambrian.

Ells, R. W., and **Ells**, S. C.

308. Reconnaissance map of parts of Albert and Westmorland counties, New Brunswick: Canada Geol. Survey, Map 35A, 1911. Scale 1:62500.

Shows location of oil-shale deposits.

Ellsworth, C. E.

309. Placer mining in the Fairbanks and Circle districts [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 240–245, 1912.

Emerson, F. V.

310. Some early physiographic inferences: Science, new ser., vol. 35, pp. 374–375, March 8, 1912.

Emmons, William H.

311. The mineral composition of the primary ore as a factor determining the vertical extent of the secondary sulfide zone: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 359–360, August 19, 1912.

The agency of manganese in the superficial alteration and secondary enrichment of gold deposits in the United States: Am. Inst. Min. Eng., Trans., vol. 42, pp. 3–73, 3 figs., 1912. See no. 401 of the bibliography for 1910, U. S. Geol. Survey, Bull. 495.

Engineering and Mining Journal.

312. A new iron ore deposit in Pennsylvania?: Eng. and Min. Jour., vol. 93, pp. 632, 683–684, March 30 and April 6, 1912.

Ernest, T. R.

A study of sand-lime brick. See Parr and Ernest, no. 831.

Evans, George Watkin.

313. The coal fields of King County: Washington Geol. Survey, Bull. no. 3, 247 pp., 23 pls. (incl. geol. map), 59 figs., 1912.

Fairchild, Herman L.

314. The glacial waters in the Black and Mohawk valleys: New York State Mus., Bull. 160, 47 pp., 28 pls. and maps, 1 fig., 1912.

315. The closing phase of glaciation in New York: New York State Mus., Bull. 158, pp. 32–35, 2 pls., 1912.

316. Closing phase of glaciation in New York: Abstract, Science, new ser., vol. 35, p. 316, February 23, 1912; Abstract (with discussion by J. W. Spencer), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 737–738, December 17, 1912.

317. Postglacial erosion and oxidation (discussion): Geol. Soc. America, Bull., vol. 23, no. 2, p. 295, June 1, 1912.

Faribault, E. R.

318. Gold-bearing series of the basin of Medway River, Nova Scotia: Canada Geol. Survey, Summ. Rept., 1911, pp. 334–340, 1912.

Farrell, J. H.

319. Practical field geology; including a guide to the sight recognition of one hundred and twenty common or important minerals, by Alfred J. Moses. xi, 273 pp., 67 figs., 4 tables. New York, McGraw-Hill Book Company, 1912.

Fenneman, N. M.

320. On the preglacial Miami and Kentucky rivers: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 736, December 17, 1912.

Fenner, Clarence N.

321. The various forms of silica and their mutual relations: Washington Acad. Sci., Jour., vol. 2, no. 20, pp. 471–480, December 4, 1912.

Study of a contact metamorphic ore deposit; the Dolores mine, at Matehuala, S. P. L., Mexico. See Spurr and others, no. 1016.

Ferguson, H. G., and **Bateman**, A. M.

322. Geologic features of tin deposits: Econ. Geology, vol. 7, no. 3, pp. 209–262, 1 pl., 17 figs., April-May, 1912.

Fettke, Charles R.

323. Limonite deposits of Staten Island, New York: School of Mines Quart., vol. 33, no. 4, pp. 382–391, July, 1912.

Feust, Arthur.

324. The Chontales mining district, Nicaragua: Min. and Sci. Press, vol. 105, pp. 720–722, 5 figs., December 7, 1912.

Includes notes on the geological features and the occurrence of the gold ores.

Finney, Marian.

325. The limbs of Lysorophus: Jour. Morphology, vol. 23, no. 4, pp. 664–666, December, 1912.

Foerste, August F.

326. Report on the value of the Dix River as a source of water power: Kentucky Geol. Survey, Bull. no. 21, 63 pp., pls. and tables, with supplementary report of 3 pp., 1912.

Contains various notes on the geology of central Kentucky.

327. Strophomena and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana, and Kentucky: Denison Univ., Sci. Lab., Bull., vol. 17, pp. 17–172, 18 pls., 1912.

328. The Arnheim formation within the areas traversed by the Cincinnati geanticline: Ohio Naturalist, vol. 12, no. 3, pp. 429–456, 3 pls., January, 1912.

329. The Ordovician section in the Manitoulin area of Lake Huron: Ohio Naturalist, vol. 13, no. 2, pp. 37–48, 1 fig. (map), December, 1912.

Fohs, F. Julius.

330. Coals of the region drained by the Quicksand creeks in Breathitt, Floyd, and Knott counties: Kentucky Geol. Survey, Bull. no. 18, 79 pp., 8 pls. (maps), 1912.

Foote, H. W., and **Bradley**, W. M.

331. On solid solution in minerals; II. The chemical composition of analcite: Am. Jour. Sci., 4th ser., vol. 33, pp. 433–439, May, 1912.

332. The chemical composition of nephelite: Am. Jour. Sci., 4th ser., vol. 33, pp. 439–441, May, 1912.

Foote, Warren M.

333. Preliminary note on the shower of meteoric stones near Holbrook, Navajo County, Arizona, July 19, 1912, including a reference to the Perseid swarm of meteors visible from July 11 to August 22: Am. Jour. Sci., 4th ser., vol. 34, pp. 437–456, 17 figs., November, 1912.

Foote Mineral Company.

334. Meteorites. Part I. Prices of individual specimens. Part II. The Foote collection, with synopsis of the Rose-Tschermak-Brezina classification. 64 pp., 11 pls., 1 fig. Philadelphia, Foote Mineral Company, November 15, 1912.

Ford, William E.

335. Dana's Manual of mineralogy. Thirteenth edition. 460 pp., 10 pls. 357 figs. New York, John Wiley & Sons, 1912.

Ford, William E.—Continued.

336. Ueber einige Herderitkrystalle von Auburn, Maine: Zeits. Krystal., Bd. 50, H. 2, pp. 97–100, 5 figs., 1912.

Describes herderite crystals from Maine.

337. George Jarvis Brush [1831–1912]: Science, new ser., vol. 35, pp. 409–411, March 15, 1912.

Includes a list of his published works.

Ford, W. E., and **Bradley,** W. M.

338. Pseudomorphs after stibnite from San Luis Potosi, Mexico: Am. Jour. Sci., 4th ser., vol. 34, pp. 184–186, 3 figs., August, 1912.

Fréchette, Howells.

339. Western portion of Torbrook iron ore deposits, Annapolis County, Nova Scotia: Canada, Dept. Mines, Mines Branch, Bull. no. 7, 13 pp., 4 pls., map, 1912.

Free, E. E.

340. Nitrate prospects in the Amargosa Valley, near Tecopa, Cal.: U. S. Dept. Agr., Bur. Soils, Circ. no. 73, 6 pp., 4 figs., December 26, 1912.

Includes notes on the geology and geologic history of the region.

341. Potash and the dry lake theory. [Published by the Railroad Valley Company.] 25 pp., 1912.

Fry, William H.

342. Mineral content of volcanic ashes from Kodiak: Science, new ser., vol. 36, pp. 681–682, November 15, 1912.

Describes the composition of several samples of volcanic ash thrown out in the eruption of Katmai, Alaska, in 1912.

Fuller, Myron L.

343. The New Madrid earthquake: U. S. Geol. Survey, Bull. 494, 119 pp., 10 pls., 18 figs., 1912.

344. The New Madrid earthquake: Abstract (by A. H. Brooks), Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 350–351, August 19, 1912.

345. Domestic water supplies for the farm. 180 pp., 65 figs. New York, John Wiley & Sons, 1912.

Includes a discussion of underground waters and the mode of their occurrence.

Fuller, Myron L., and **Clapp,** F. G.

346. The underground waters of southwestern Ohio; with a discussion of the chemical character of the waters by R. B. Dole: U. S. Geol. Survey, Water-Supply Paper 259, 228 pp., 9 pls., 11 figs. (incl. maps and sections), 1912.

Fullerton, Aubrey.

347. A coal mountain in the West: Coal Age, vol. 2, no. 9, p. 282, 2 figs., August 31, 1912.

Describes the occurrence of anthracite coal in Alberta.

Gale, Hoyt S.

348. Nitrate deposits: U. S. Geol. Survey, Bull. 523, 36 pp., 2 pls., 2 figs., 1912.

A general review of the occurrence and origin of nitrate deposits.

Gale, Hoyt S.—Continued.

349. Field investigations for potash in America: Am. Fertilizer, vol. 37, no. 2, pp. 38–40, July 27, 1912.

350. Field investigations for potash in America: Min. and Eng. World, vol. 37, pp. 491–492, September 14, 1912.

351. The Lila C. borax mine at Ryan, Cal.: U. S. Geol. Survey, Min. Res. U. S., 1911, pt. 2, pp. 861–865, 1 fig. (map), 1912.

Includes notes on the local geology.

352. Magnesite: U. S. Geol. Survey, Min. Res. U. S., 1911, pt. 2, pp. 1113–1127, 3 figs., 1912.

Mineral resources of the United States, 1911: Borax; magnesite. See no. 1127.

Galloway, C. F. J.

353. Bear River coal field, British Columbia: Canadian Min. Jour., vol. 33, pp. 335–336, 368–370, 8 figs., May 15 and June 1, 1912.

Galloway, J. J.

A note on the Batostomas of the Richmond series. See Cumings and Galloway, no. 245.

Ganong, W. F.

354. Notes on the natural history and physiography of New Brunswick: Nat. Hist. Soc. New Brunswick, Bull., no. 29 (vol. 6, pt. 3 [4?]), pp. 321–337, 1 pl. (map), 1911.

Gardner, James H.

355. Preliminary report on the economic geology of the Hartford quadrangle: Kentucky Geol. Survey, Bull. no. 20, pp. 1–25, 4 pls. (maps), 1912.

Describes the stratigraphy and structure and the occurrence and character of the mineral resources, chiefly coal.

356. Rock phosphate in Kentucky: Mines and Minerals, vol. 33, pp. 207–209, 3 figs., November, 1912.

Garfias, V. R.

357. The effect of igneous intrusions on the accumulation of oil in northeastern Mexico: Jour. Geology, vol. 20, no. 7, pp. 666–672, 3 figs., 1912.

Garrett, Robert E.

The Ponca City oil and gas field. See Ohern and Garrett, no. 803.

Garrey, G. H.

Study of a contact-metamorphic ore deposit; the Dolores mine, at Matehuala, S. P. L., Mexico. See Spurr and others, no. 1016.

Garrison, F. Lynwood.

358. Decrease in the value of ore shoots with depth: Min. Science, vol. 65, pp. 152–154, February 8, 1912; Min. and Eng. World, vol. 36, pp. 346–347, February 10, 1912; Min. and Sci. Press, vol. 104, pp. 558–561, 2 figs., April 20, 1912; Min. and Sci. Press, vol. 105, pp. 700–702, November 30, 1912.

359. Persistence of ore in depth: Min. and Sci. Press, vol. 105, pp. 377–378, September 21, 1912.

Geib, W. J., and Schroeder, F. C.

360. Soil survey of Marion county: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 447–468, 1 pl. (map), 1 fig., 1912.

Gibson, Thomas W.

361. Report of the Bureau of Mines, 1912: Ontario, Bureau of Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, 309 pp., illus., Toronto, 1912.

A statistical review with accompanying papers. These have been listed under their respective authors.

Gidley, James W.

362. Ten years' progress in vertebrate paleontology; Perissodactyla: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 179–181, June 1, 1912.

363. The Lagomorphs an independent order: Science, new ser., vol. 36, pp. 285–286, August 30, 1912.

Gilbert, Grove K.

364. Memoir of Edwin E. Howell: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 30–32, 1 pl. (port.), March 14, 1912.

Preface to "The earthquakes at Yakutat Bay, Alaska, in September, 1899." See Tarr and Martin, no. 1066.

Gilmore, Charles W.

365. A new mosasauroid reptile [*Globidens alabamaensis*] from the Cretaceous of Alabama: U. S. Nat. Mus., Proc., vol. 41, pp. 479–484, 2 pls., 3 figs., 1912.

366. The mounted skeletons of Camptosaurus in the United States National Museum: U. S. Nat. Mus., Proc., vol. 41, pp. 687–696, 7 pls., 4 figs., February 8, 1912.

367. Remarks on the skeleton of the dinosaur Stegosaurus: Abstract, Science, new ser., vol. 35, p. 972, June 21, 1912.

Girty, George H.

368. On some invertebrate fossils from the Lykins formation of eastern Colorado: New York Acad. Sci., Annals, vol. 22, pp. 1–8, 1 pl., April 3, 1912.

369. I—On some growth stages in *Naticopsis altonensis* McChesney; II—Notice of a Mississippian gastropod retaining coloration: Am. Jour. Sci., 4th ser., vol. 34, pp. 338–340, October, 1912.

370. Geologic age of the Bedford shale of Ohio; New York Acad. Sci., Annals, vol. 22, pp. 295–319, November 13, 1912.

Glenn, L. C.

371. A geological reconnaissance of the Tradewater River region, with special reference to the coal beds: Kentucky Geol. Survey, Bull. no. 17, 75 pp., 1 pl., 1912.

372. The geology of Webster County: Kentucky Geol. Survey, Rept. of Progress for 1910 and 1911, pp. 25–35, 1912.

373. The growth of our knowledge of Tennessee geology: Tennessee State Geol. Survey, Resources of Tennessee, vol. 2, no. 5, pp. 167–219, illus., May, 1912. [Also appears in Bulletin 1–C.]

374. The Arkansas diamond-bearing peridotite area: Abstract, Science, new ser., vol. 35, p. 312, February, 1912.

375. Arkansas diamond-bearing peridotite area (abstract, with discussion by A. H. Purdue): Geol. Soc. America, Bull., vol. 23, no. 4, p. 726, December 17, 1912.

Goesse, John B., and **Rueppel**, George E.

376. Seismology in St. Louis University: St. Louis Univ. Bull., vol. 7, no. 5, 53 pp., 3 pls., 8 figs., December, 1911.

Goetz, Alois.

377. The eastern Michigan iron range: Eng. and Min. Jour., vol. 93, pp. 1090–1092, 1 fig., June 1, 1912.

Goldschmidt, V.

On quartz from Alexander County, North Carolina. See Pogue and Goldschmidt, no. 864.

Goldthwait, J. W.

378. Records of postglacial changes of level in Quebec and New Brunswick: Canada Geol. Survey, Summ. Rept., 1911, 296–302, 1912.

González, F., **Grothe**, Albert, and **Salazar S**, Leopoldo.

379. The mining industry of Mexico. No. 1, State of Hidalgo. Part 1, 74 pp., pls., Part 2, pp. 77–108, pls., 1911. [See also Grothe and Salazar, no. 405.]

Includes various notes on the geology and the occurrence and character of the ores.

Goodspeed, G. E., jr.

Recent literature on economic geology. See Loughlin and Goodspeed, no. 681.

Gordon, C. H.

380. Cave marble (cave onyx) in Tennessee: Tennessee Geol. Survey, Resources of Tennessee, vol. 2, no. 8, pp. 307–317, 3 figs., August, 1912.

381. Onyx deposits in east Tennessee: Abstract, Science, new ser., vol. 35, pp. 312–313, February 23, 1912.

382. Onyx deposits in east Tennessee: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 729, December 17, 1912.

Gordon, C. H., and **Jarvis**, R. P.

383. Iron deposits in the Tuckahoe district, east Tennessee: Tennessee State Geol. Survey, The Resources of Tennessee, vol. 2, no. 12, pp. 458–478, 3 figs., map, December, 1912.

Gottschalk, V. H., and **Buehler**, H. A.

384. Oxidation of sulphides (second paper): Econ. Geology, vol. 7, no. 1, pp. 15–34, 1 fig., January, 1912.

Gould, Charles N.

385. Petroleum and natural gas in Oklahoma: Econ. Geology, vol. 7, no. 8, pp. 719–731, December, 1912.

386. Geology of natural gas: Natural Gas Jour., 6th year, no. 10, pp. 488–491, October, 1912.

Grabau, Amadeus W.

387. Studies of Gastropoda, IV; Value of the protoconch and early conch stages in the classification of Gastropoda: Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 753–766, 18 figs., Cambridge, U. S. A., 1912.

388. Syllabus of historical geology. 51 pp. New York, A. G. Seiler, 1912.

389. Stratigraphic and paleontologic features of ancient delta deposits: Abstract, Science, new ser., vol. 35, p. 317, February 23, 1912; Abstract (with discussion by J. M. Clarke, David White, G. W. Stose, Arthur Keith, E. T. Wherry, and H. B. Kümmel), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 743–746, December 17, 1912.

Grabau, Amadeus W.—Continued.

390. Structure of the Helderberg front: Abstract, Science, new ser., vol. 35, p. 319, February 23, 1912; Abstract (with discussion by J. B. Woodworth), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 746–747. December 17, 1912; Abstract, New York Acad. Sci., Annals, vol. 21, p. 210, 1912.

Grabau, A. W., and **Reed,** Margaret.

391. Mutations of *Spirifer mucronatus:* Abstract, Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 767–768, Cambridge, U. S. A., 1912.

Granger, Walter.

Notes on the Tertiary deposits of the Bighorn basin. See Sinclair and Granger, no. 985.

Grant, U. S., and **Higgins,** D. F.

392. Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, p. 100, February 19, 1912.

Grasty, John Sharshall.

393. An unusual occurrence of the mineral evansite: Virginia, Univ., Philos. Soc., Bull., Sci. ser., vol. 1, no. 8, pp. 223–230, 1 fig., January, 1912.

Describes the occurrence, characters, and composition of evansite from Alabama.

Gratacap, L. P.

394. A popular guide to minerals, with chapters on the Bement collection of minerals in the American Museum of Natural History, and the development of mineralogy; for use of visitors to public cabinets of minerals and for elementary teaching in mineralogy. 330 pp., 74 pls., 400 figs., map (in pocket). New York, D. Van Nostrand Company, 1912.

395. An unusual specimen of *Mytilus middendorfii* Grewingk, from Alaska: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 69–70, 1 pl., 1912.

Greenawalt, William E.

396. The tungsten deposits of Boulder Co., Colorado: Cornell Civil Engineer, vol. 20, no. 4, pp. 197–202, January, 1912.

Gregory, William K.

397. Ten years' progress in vertebrate paleontology: marsupials, insectivores, and primates: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 187–196, June 1, 1912.

398. Notes on the principles of quadrupedal locomotion and on the mechanism of the limbs in hoofed animals: New York Acad. Sci., Annals, vol. 22, pp. 267–294, 1 pl., 7 figs., October 18, 1912.

399. Note on the upper Eocene titanotheroid *Telmatherium? incisivum* Douglass from the Uinta basin: Science, new ser., vol. 35, p. 546, April 5, 1912.

Proposes for this species the new generic name *Sthenodectes.*

400. A new restoration of a titanothere: Am. Mus. Jour., vol. 12, no. 1, pp. 15–17, 2 figs., January, 1912.

401. On the limbs of Eryops and the origin of limbs from paired fins: Abstract, New York Acad. Sci., Annals, vol. 21, pp. 192–193, 1912.

Gregory, William K.—Continued.

402. Further notes on the evolution of paired fins: Abstract, New York Acad. Sci., Annals, vol. 21, p. 216, 1912.

403. Notes on the origin of paired limbs of terrestrial vertebrates: Abstract, New York Acad. Sci., Annals, vol. 21, pp. 219–220, 1912.

Griffith, William, and **Conner**, Eli T.

404. Mining conditions under the City of Scranton, Pa.: U. S. Bureau Mines, Bull. 25, 89 pp., 29 pls. (in case), 1912.

Grothe, Albert.

The mining industry of Mexico. No. 1, State of Hidalgo. See González and others, no. 379.

Grothe, Albert, and **Salazar S**, Leopoldo.

405. La industria minera de México. Tomo 1, Estados de Hidalgo y México. 319 pp., pls., México, 1912. [See also González and others, no. 379.]

Includes various notes on the geology and the occurrence and character of the ore deposits of the states of Hidalgo and Mexico, Mexico.

Guardiola, Ricardo.

406. Sobre el origen de los criaderos de Mayari: Revista minera, Año 63, pp. 25–27, January 16, 1912.

Discusses the origin of the iron-ore deposits of Mayari, Cuba.

Guillotel, F.

407. Ressources minérales des États-Unis; le cuivre, le charbon, et le fer: Revue de Géog., Annuelle, t. 4, pp. 309–357, 1910.

A general account of the occurrence and production of copper, coal, and iron in the United States.

Gunter, Herman.

The underground water supply of west central and west Florida. See Sellards and Gunter, no. 963.

Roads and road materials of Florida. See Sellards and others, no. 964.

Gunther, C. Godfrey.

408. The examination of prospects; a mining geology. 222 pp., 79 figs. New York, McGraw-Hill Book Company, 1912.

Guppy, R. J. Lechmere.

409. On a collection of fossils from Springvale, near Couva, Trinidad: Agric. Soc. Trinidad and Tobago, Proc., vol. 10, pt. 11, pp. 447–461, November, 1910.

410. Fossils from Springvale, near Couva, Trinidad: Agric. Soc. Trinidad and Tobago, Proc., vol. 11, pt. 3, pp. 194–203, 3 pls., March, 1911.

Describes the character and occurrence of Miocene beds and new species of Mollusca.

411. An account of some recent geological discoveries in the West Indies: Agric. Soc. Trinidad and Tobago, Proc., vol. 12, pts. 1–2, pp. 22–35, 1 pl., January–February, 1912.

412. Note on Dr. Watts's remarks on the geology of Antigua: Agric. Soc. Trinidad and Tobago, Proc., vol. 12, pt. 3, pp. 75–78, March, 1912.

413. On the geology of Antigua and other West Indian islands with reference to the physical history of the Caribbean region: Agric. Soc. Trinidad and Tobago, Proc., vol. 12, pt. 6, pp. 182–207, 5 pls., June, 1912.

Guppy, R. J. Lechmere—Continued.

414. Further note on the Caroni series at Savaneta: Agric. Soc. Trinidad and Tobago, Proc., vol. 12, pt. 10, pp. 330–334, October, 1912.

Haanal, Eugene.

Summary report of the Mines branch of the Department of Mines for the calendar year ending December 31, 1911. See no. 166.

Hafer, Claude.

415. The mines of the Sonora Valley, Sonora, Mexico: Min. and Eng. World. vol. 36, pp. 903–904, 4 figs., April 27, 1912.

Hager, Dorsey.

416. Value of geology in the petroleum industry: Min. and Eng. World. vol. 35, pp. 435–437, 1 fig., September 2, 1911; vol. 36, p. 680, March 23, 1912.

Hague, Arnold.

417. Geological history of the Yellowstone National Park: U. S. Dept. of the Interior, 24 pp., 9 figs., 1912.

418. Memoir of Samuel Franklin Emmons: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 12–28, 1 pl. (port.), March 14, 1912.

Includes a list of his writings.

419. Biographical memoir of Samuel Franklin Emmons, 1841–1911: Nat. Acad. Sci., Biog. Mem., vol. 7, pp. 309–334, 1 pl. (port.), December, 1912.

Includes a list of his scientific writings.

Hahn, F. F.

420. The form of salt deposits: Econ. Geology, vol. 7, no. 2, pp. 120–135, 4 figs., February–March, 1912.

421. On the Dictyonema-fauna of Navy Island, New Brunswick: New York Acad. Sci., Annals, vol. 22, pp. 135–160, 3 pls., 3 figs., July 25, 1912.

Hahn, F. Felix.

422. E. O. Ulrich's "Revision der Paläozoischen Systeme"—ein Markstein der Stratigraphie als Wissenschaft? [E. O. Ulrich's "Revision of the Paleozoic systems"—a land-mark of stratigraphy as a science?]: Geol. Rundschau, Bd. 3, pp. 554–556, 1912.

Hall, R. Dawson.

423. Georges Creek coal field, Maryland: Coal Age, vol. 1, pp. 10–14, 10 figs., October 14, 1911.

Hammon, W. D.

424. Potash solutions in the Searles Lake region [California]: Min. Sci., vol. 65, pp. 372–373, 391–392, April 25 and May 2, 1912.

Includes an account of the geology of the region.

425. The Searles Lake potash deposit: Eng. and Min. Jour., vol. 93, pp. 891–895, 23 figs., May 18, 1912.

Hance, J. H.

426. The Glendive lignite field, Dawson County, Montana: U. S. Geol. Survey, Bull. 471, pp. 271–283, 2 pls. (map and sections), 1912.

Hannibal, Harold.

427. A synopsis of the recent and Tertiary freshwater Mollusca of the Californian province, based upon an ontogenetic classification: Malacological Soc., Proc., vol. 10, pp. 112–166, 167–211, 1912.

Harder, Edmund Cecil.

428. Iron-ore deposits of the Eagle Mountains, California: U. S. Geol. Survey, Bull. 503, 81 pp., 13 pls., 4 figs., 1912.

Harris, Gilbert D.

429. Oil concentration about salt domes: Science, new ser., vol. 35, pp. 546–547, April 5, 1912.

430. Dome theories as applied to Gulf coast geology: Science, new ser., vol. 36, pp. 173–174, August 9, 1912.

Hart, Charles A.

431. Note on "some early physiographic inferences": Science, new ser., vol. 35, p. 693, May 3, 1912.

Hartnagel, C. A.

432. Classification of the geologic formations of the State of New York: New York State Mus., Handbook 19 (of the State of New York Education Department) 96 pp., 2 tables, April, 1912.

A second edition, much enlarged, of Handbook 19, entitled Classification of New York series of geologic formations, by John M. Clarke, published July, 1903.

Harvie, Robert.

433. Geology of Orford map area, Quebec, southern part of "serpentine belt," Bolton township: Canada Geol. Survey, Summ. Rept., 1911, pp. 286–292, 1912.

Notes on a discovery of a telluride gold ore at Opasatica and its probable relations to the gold ores of the Porcupine and neighboring districts: Canadian Min. Inst., Jour., vol. 14, pp. 164–170, 1 fig., 1912. See no. 473 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 44.

Hatschek, E., and **Simon**, A. L.

434. Gels, gelatinous quartz, and gold-ore deposition: Min. and Eng. World, vol. 37, pp. 280–282, August 17, 1912.

Hay, Oliver Perry.

435. The Pleistocene age and its vertebrata: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 539–784, 2 pls. (maps), 80 figs., 1912.

436. Ten years' progress in vertebrate paleontology; Chelonia: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 212–220, June 1, 1912.

437. The recognition of Pleistocene faunas: Smithsonian Misc. Coll., vol. 59, no. 20, 10 figs. (maps), August 17, 1912.

Discusses the geographic distribution of Quaternary Mammalia in North America.

438. On an important specimen of Edestus; with description of a new species, *Edestus mirus*: U. S. Nat. Mus., Proc., vol. 42, pp. 31–38, 2 pls., April 25, 1912.

439. American Permian vertebrates: Am. Naturalist, vol. 46, pp. 561–565, September, 1912.

Hayes, C. Willard.

The Mayari and Moa iron-ore deposits in Cuba: Am. Inst. Min. Eng., Trans., vol. 42, pp. 109–115, 1912. See no. 481 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Hayford, John F.

440. Isostasy, a rejoinder to the article by Harmon Lewis: Jour. Geology, vol. 20, no. 6, pp. 562–578, 1912.

Hayford, John F., and **Bowie**, William.

441. The effect of topography and isostatic compensation upon the intensity of gravity: U. S. Coast and Geodetic Survey, Special publication no. 10, 132 pp., 19 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 7, pp. 189–191, April 4, 1912.

Includes a discussion of the relations between gravity anomalies and geologic formations.

Heim, Arnold.

442. Nordwest-Grönlands Gneisgebirge: Geologische Charakterbilder (H. Stille), Heft 6, 6 pls., and explanatory text, 1911.

Gives a brief outline of the general geology of northwestern Greenland and reproductions of photographs, with explanatory text, of the crystalline (pre-Cambrian) highlands.

443. West-Grönlands Basalt- und Sedimentgebirge: Geologische Charakterbilder (H. Stille), Heft 7, 8 pls., and explanatory text, 1911.

Gives reproductions of photographs, with explanatory text, of characteristic views of Tertiary basalt and Cretaceous sedimentary strata along the coast of western Greenland.

Heindl, Alexander J.

444. Graphic representation of oil-field structure: Min. and Sci. Press, vol. 105, pp. 824–827, 4 figs., December 28, 1912.

Henderson, Charles W., and **Winstanley**, J. B.

445. Bibliography of the geology, paleontology, mineralogy, petrology, and mineral resources of Oregon, with subject index by Graham J. Michael: Oregon, Univ., Bull., new ser., vol. 10, no. 4, 49 pp., December, 1912.

Henderson, Junius.

Mollusca from the Tertiary strata of the West. See Cockerell and Henderson, no. 213.

Hendrixson, W. S.

Underground water resources of Iowa. See Norton and others, no. 800.

Henegar, Herbert B.

446. Barite deposits in the Sweetwater district: Tennessee State Geol. Survey, The Resources of Tennessee, vol. 2, no. 11, pp. 424–429, 3 figs., November, 1912.

Hennen, Ray V.

447. Doddridge and Harrison counties: West Virginia Geol. Survey, 712 pp., 25 pls., 5 figs., 3 maps (in atlas), 1912.

Describes the history and physiography, the geologic structure and stratigraphy (Carboniferous strata), and the mineral resources, chiefly petroleum, natural gas, and coal.

Herald, Frank A.

448. The Terry lignite field, Custer County, Montana: U. S. Geol. Survey, Bull. 471, pp. 227–270, 3 pls. (map and sections), 1912.

Hershey, Oscar H.

449. Some Tertiary and Quaternary geology of western Montana, northern Idaho, and eastern Washington: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 75, March 1, 1912.

450. Geological reconnaissance in northeastern Nicaragua: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 493–516, 1 fig., October 22, 1912.

Describes Quaternary and Tertiary deposits in the Pis-Pis district, Nicaragua.

Hershey, Oscar H.—Continued.

451. Some Tertiary and Quaternary geology of western Montana, northern Idaho, and eastern Washington: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 517–536, 1 pl., October 22, 1912.

Describes glaciation in Deer Creek Valley, Montana, and in the Coeur d'Alene district, Idaho; the terraces of the region around Kellogg, Idaho; the origin and age of Coeur d'Alene Lake; the valleys of the Clearwater country, Idaho; and the plains and valleys of eastern Washington; and summarizes the geologic history of the region in Tertiary and Quaternary time.

452. The Belt and Pelona series: Am Jour. Sci., 4th ser., vol. 34, pp. 263–273, September, 1912.

453. Geology of the Pis Pis mining district in Nicaragua: Min. and Sci. Press, vol. 104, pp. 270–272, February 17, 1912.

454. Genesis of lead-silver ores in Wardner district, Idaho: Min. and Sci. Press, vol. 104, pp. 750–753, 786–790, 825–827, 6 figs. (incl. geol. map), June 1, 8, and 15, 1912.

Hess, Eva.

Bibliography of the geology and mineralogy of tin. See Hess and Hess, no. 458.

Hess, Frank L.

455. Tin resources of Alaska: U. S. Geol. Survey, Bull. 520, pp. 89–92, 1912.

456. Rare minerals of the South: Manufacturers Record, vol. 61, no. 7, pt. 2, pp. 72–73, February 22, 1912.

457. Prospecting for vanadium: Min. and Sci. Press, vol. 105, pp. 366–367, September 21, 1912.

Mineral resources of the United States, 1911; Tungsten; vanadium; uranium; titanium; molybdenum; nickel; cobalt; tantalum; tin; antimony; bismuth; selenium; arsenic. See no. 1127.

Zirconiferous sandstone near Ashland, Virginia. See Watson and Hess, no. 1165.

Hess, Frank L., and **Hess**, Eva.

458. Bibliography of the geology and mineralogy of tin: Smithsonian Misc. Coll., vol. 58, no. 2, pp. i–v, 1–408, 1912.

Hewett, D. F.

459. A graphic method for dips on geologic sections: Econ. Geology, vol. 7, no. 2, pp. 190–191, 1 pl., February–March, 1912.

Higgins, D. F.

460. The planetable in detailed geologic mapping (discussion): Econ. Geology, vol. 7, no. 5, pp. 502–506, 1 fig., August, 1912.

Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska. See Grant and Higgins, no. 392.

Higgins, W. C.

461. The Union Chief and Santaquin mines [Utah]: Salt Lake Min. Rev., vol. 14, no. 10, pp. 11–16, 9 figs., August 30, 1912.

Includes notes on the local geology and the occurrence and character of the iron-lead-silver ores.

Hilgard, E. W.

462. A new development in the Mississippi delta: Pop. Sci. Monthly, vol. 80, no. 3, pp. 236–245, 1 pl. (map), March, 1912.

Hill, James M.

463. The mining districts of the western United States, with a geologic introduction by Waldemar Lindgren: U. S. Geol. Survey, Bull. 507, 309 pp., 16 pls. (maps), 1 fig., 1912.

A catalog of the mining districts, giving metals produced, kind of deposit, geologic formation, and other data.

Hill, Robert T.

464. Marble deposits of the Inyo Mountains [California]: Min. and Sci. Press, vol. 105, pp. 86–87, July 20, 1912.

Hille, F.

465. [Origin of petroleums]: Canadian Min. Jour., vol. 33, pp. 145–147, March 1, 1912.

Hills, Victor G.

466. Magmatic origin of ore-forming solutions: Min. and Sci. Press, vol. 104, p. 703, May 18, 1912.

467. Tungsten and the scheelite mines in Nova Scotia: Min. Soc. Nova Scotia, Jour., vol. 17, pp. 55–60, 1912.

468. The scheelite deposits of Nova Scotia: Canadian Min. Jour., vol. 33, pp. 679–680, October 1, 1912.

469. Tungsten mining in Nova Scotia: Colorado Sci. Soc., Proc., vol. 10, pp. 203–210, 2 pls., December, 1912.

Includes a brief account of the geology and occurrence of the tungsten ore; gives also a note on the occurrence of tungsten at Loon Lake, Washington.

Hinds, Henry.

470. The coal deposits of Missouri: Missouri Bur. Geology and Mines, vol. 11, 2d ser., 503 pp. 23 pls. (incl. maps and geologic sections), 97 figs., 7 maps, [1912?].

Hitchcock, Charles H.

471. Hawaii and its volcanoes. 2d ed., with supplement. Honolulu, Hawaii, 1911.

The second edition differs from the first only in the addition of the supplement of 8 pp. and 7 pls.

472. The geology of Oahu in its relation to the artesian supply: Hawaiian Forester and Agriculturist, vol. 8, no. 1, pp. 27–29, January, 1911.

473. The Strafford quadrangle: Vermont, State Geologist, Eighth Rept., pp. 100–145, 13 pls., 1912.

Describes the stratigraphy and geologic structure.

474. Tertiary deposits of Oahu: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 71, March 14, 1912.

475. The Hawaiian earthquakes of 1868: Seism. Soc. America, Bull., vol. 2, no. 3, pp. 181–192, 2 figs. (maps), September, 1912.

Hobbs, William Herbert.

476. Earth features and their meaning: an introduction to geology for the student and general reader. xxxix, 506 pp., 24 pls., 493 figs. New York, The Macmillan Company, 1912.

477. Some considerations bearing upon the origin of lava: Abstract, Science, new ser., vol. 35, p. 790, May 17, 1912.

478. One phase of Washington science: Science, new ser., vol. 36, pp. 477–479, 1 fig., October 11, 1912.

Hodge, James M.

479. Report on the coals of the three forks of the Kentucky River: Kentucky Geol. Survey, Bull. no. 11, 280 pp., 1 pl., 323 figs. (maps and sections), 1910 [distributed 1912 or 1913].

480. Report on the upper Cumberland coal field; the region drained by Poor and Clover forks in Harlan and Letcher counties: Kentucky Geol. Survey, Bull. no. 13, 223 pp., 6 pls. (incl. map), 267 figs., 1912.

Hodge, W. R.

481. West Shiningtree gold district [Ontario]: Eng. and Min. Jour., vol. 94, pp. 343–345, 4 figs., August 24, 1912.

Höfer, Hans von.

482. Temperature in oil regions: Econ. Geology, vol. 7, no. 6, pp. 536–541, September, 1912.

Hoff, L. R.

Asbestos and its uses. See Pearson and Hoff, no. 838.

Hole, Allen David.

483. Terraces of the Whitewater River near Richmond, Indiana: Indiana Acad. Sci., Proc., 1911, pp. 71–81, 5 figs., 1912.

484. Soil survey of Hancock, Johnson, and Shelby counties: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 31–82, 3 pls. (maps), 6 figs., 1912.

485. Glaciation in the Telluride quadrangle, Colorado: Jour. Geology, vol. 20, nos. 6, 7, and 8, pp. 502–529, 605–639, 710–737, 1 pl. (map), 15 figs., 1912.

Holland, W. J.

486. A preliminary account of the Pleistocene fauna discovered in a cave opened at Frankstown, Pennsylvania, in April and May, 1907: Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 748–752, Cambridge, U. S. A., 1912.

487. Ten years' progress in vertebrate paleontology; Jurassic dinosaurs: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 204–207, June 1, 1912.

Hollick, Arthur.

488. The relations of paleobotany to botany; ecology: Am. Naturalist, vol. 46, pp. 239–243, April, 1912; Abstract, Science, new ser., vol. 35, p. 148, January 26, 1912.

489. Additions to the paleobotany of the Cretaceous formation on Long Island, No. III: New York Bot. Garden, Bull., vol. 8, no. 28, pp. 154–170, 9 pls., November 23, 1912.

Holmquist, P. J.

490. Några jämförelsepunkter emellan nordamerikansk och fennskandisk prekambrisk geologi: Geol. Fören. i Stockholm, Förh., Bd. 31, pp. 25–51, January, 1909.

Compares the pre-Cambrian formations of North America with those of Scandinavia and Finland.

Hopkins, P. E.

491. Notes on McArthur township: Ontario Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 278–280, 2 figs., 1912.

Gives notes on the geology of pre-Cambrian rocks and the occurrence of gold.

Hopkins, Thomas Cramer.

492. Glacial erosion in the San Juan Mountains, Colorado: Wyoming Hist. and Geol. Soc., Proc. and Coll., vol. 11, pp. 31–44, 8 pls., 1910.

Hopper, Walter E.

The Caddo oil and gas field, Louisiana: Am. Inst. Min. Eng., Trans., vol. 42, pp. 409–435, 10 figs., 1912. See no. 516 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Hore, Reginald E.

493. Decrease of values in ore shoots with depth: Canadian Min. Jour., vol. 33, pp. 260–263, April 15, 1912.

494. Mines and ores of Porcupine [Ontario]: Eng. and Min. Jour., vol. 93, pp. 891–895, 23 figs., May 4, 1912.

495. The copper-mining industry of Michigan: Min. and Eng. World, vol. 36, pp. 601–603, 656–658, 707–710, 763–767, 21 figs., March 16, 23, and 30, April 6, 1912.

496. Origin of the Sudbury nickel and copper deposits [Ontario]: Min. and Eng. World, vol. 36, pp. 1345–1349, 8 figs., June 29, 1912.

497. Silver mining at Cobalt, Ontario: Min. and Sci. Press, vol. 105, pp. 74–77, 8 figs., July 20, 1912.

On the nature of some Porcupine gold quartz deposits: Canadian Min. Inst., Jour., vol. 14, pp. 171–184, 14 pls., 1912. See no. 518 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 47.

Geology of the Cobalt district, Ontario, Canada: Am. Inst. Min. Eng., Trans., vol. 42, pp. 480–499, 12 figs., 1912. See no. 520 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

The silver fields of Nipissing, Ontario: Canadian Min. Inst., Jour., vol. 14, pp. 612–636, 13 pls., 1912. See no. 521 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 47.

The copper industry of Michigan. See Allen and others, no. 13.

Hornaday, W. D.

498. The oil fields of Texas and their development: Min. and Eng. World, vol. 36, pp. 1299–1300, 1 fig., June 22, 1912.

499. Importance of Mexico as a petroleum producer: Min. and Eng. World, vol. 36, pp. 1307–1309, 1 fig., June 22, 1912.

500. The Santa Maria graphite mines, Mexico: Min. and Eng. World, vol. 37, pp. 1041–1043, 1 fig., December 7, 1912.

Hoskin, Arthur J.

Geology and ore deposits of the Alma district, Park County, Colorado. See Patton and others, no. 834.

Hotchkiss, W. O., and **Thwaites**, F. T.

501. Map of Wisconsin showing geology and roads, 1911. Scale, 6 miles equals 1 inch. Wisconsin Geol. and Nat. Hist. Survey [1912].

Includes a table of the geologic formations and an outline of the geologic history of Wisconsin.

Hovey, Edmund Otis.

502. The Geological Society of America: Science, new ser., vol. 35, pp. 310–320, February 23, 1912.

Gives an account of the twenty-fourth annual meeting in Washington, D. C., December, 1912, and abstracts of papers presented.

503. Proceedings of the twenty-fourth annual meeting of the Geological Society of America, held at Washington, D. C., December 27, 28, 29, and 30, 1911: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 1–68, 6 pls., March 14, 1912.

Hovey, Edmund Otis—Continued.

504. Abstracts of papers presented at the twenty-fourth annual meeting of the society, but not published in full in the preceding pages of this volume, together with discussions of papers so far as preserved: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 719–747, December 17, 1912.

505. Geological sketch of the Hudson River region from Newburgh to the sea: The geology, fauna, and flora of the lower Hudson Valley, prepared by the American Museum of Natural History and the New York Botanical Gardens . . . , pp. 3–19, 1 fig. (map), September 8, 1912.

506. Cave material from a Mexican mine: Am. Mus. Jour., vol. 12, no. 6, p. 218, October, 1912.

Gives brief notes on minerals from a cave near Chihuahua, Mexico.

507. New accessions of meteorites [in the American Museum of Natural History]: Am. Mus. Jour., vol. 12, no. 7, pp. 257–258, November, 1912.

508. The seismograph at the American Museum [of Natural History, New York]: Am. Mus. Jour., vol. 12, no. 8, pp. 297–299, 3 figs., December, 1912.

509. The Kingston, New Mexico, siderite: New York Acad. Sci., Annals, vol. 22, pp. 335–337, 5 pls., December 27, 1912.

Hovey, Horace Carter.

510. Hovey's Handbook of the Mammoth Cave of Kentucky; a practical guide to the regulation routes, with maps and illustrations. 64 pp. Louisville, Kentucky, John P. Morton & Company, 1909.

511. Mammoth Cave of Kentucky (Hovey and Call); with an account of Colossal Cavern. Revised edition, 131 pp., illus. Louisville, John P. Morton & Company, 1912.

512. Bibliography of the Mammoth Cave: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 747, December 17, 1912.

Howe, C. D.

513. Distribution and reproduction of the forest in relation to underlying rocks and soils: Nova Scotia, Commission of Conservation, Forest Conditions of Nova Scotia, pp. 43–93, 8 pls., Ottawa, Canada, 1912.

Includes notes on the character and distribution of the rocks and physical features of Nova Scotia.

Howe, Marshall A.

514. Reef-building and land-forming seaweeds: Abstract, Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 1, pp. 137–138, 1912.

515. The building of "coral" reefs: Science, new ser., vol. 35, pp. 837–842, May 31, 1912.

Hubbard, George D.

Geology of the Columbus quadrangle. See Stauffer and others, no. 1025.

Hubbard, L. L.

516. Geological notes on the Lake Superior copper formation: Lake Superior Min. Inst., Proc., vol. 17, pp. 9–11, 1912.

517. In the Lake Superior area what influence, if any, did the thickness and contour of foot wall beds have upon the subsequent deposition and distribution of copper in overlying beds? (with discussion): Lake Superior Min. Inst., Proc., vol. 17, pp. 227–237, 1912.

Hudson, George H.

518. Rill channels and their cause, a rock-surface character of glacial origin: Vermont, State Geologist, Eighth Rept., pp. 232–246, 10 pls., 1912.

519. A fossil starfish with ambulacral covering plates: Ottawa Naturalist, vol. 26, no. 2, pp. 22–26, 3 pls., nos. 3–4, pp. 45–52, May, June–July, 1912.

Describes *Protopalæaster narrawayi* n. gen. and n. sp. from the Ordovician, of Ottawa, Ontario.

Huene, Friedrich von.

520. Beiträge zur Kenntnis des Schädels von Eryops: Anatomischer Anzeiger, Bd. 41, no. 4, pp. 98–104, 8 figs., 1912.

Describes the skull of Eryops from Permian deposits of Texas.

521. Der Unterkiefer von Diplocaulus: Anatomischer Anzeiger, Bd. 42, no. 19, pp. 472–475, 3 figs., 1912.

Describes a lower jaw of Diplocaulus from the Permian of Baylor County, Texas.

Hull, Edward.

522. Monograph on the suboceanic physiography of the north Atlantic Ocean; with a chapter on the suboceanic physical features off the coast of North America and the West Indian Islands, by Joseph William Winthrop Spencer. 41 pp., 11 pls. (maps). London, Edward Stanford, 1912.

Huntington, Ellsworth.

523. William Morris Davis, geographer: Geog. Soc. Philadelphia, Bull., vol. 10, no. 4, pp. 26–36 (224–234), 1 pl. (portrait), October, 1912.

524. The Peninsula of Yucatan: Am. Geog. Soc., Bull., vol. 44, no. 11, pp. 801–822, 11 figs., November, 1912.

Includes notes on physiographic features.

Hussakof, L.

525. Notes on Devonic fishes from Scaumenac Bay, Quebec: New York State Mus., Bull. 158, pp. 127–139, 4 pls., 5 figs., 1912.

526. The Cretaceous chimæroids of North America: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 195–228, 2 pls., 21 figs., 1912.

Huston, George.

527. Prichard formation rocks [Coeur d'Alene region, Idaho]: Min. and Eng. World, vol. 36, p. 305, February 3, 1912.

Gives notes on the local geology and the character, occurrence, and origin of the ores.

Hyde, Jesse E.

528. The geological history of Fairfield County, Ohio. Extract from History of Fairfield County and representative citizens, by Charles C. Miller, pp. 203–223. Chicago, Ill., Richmond-Arnold Pub. Co., April 15th, 1912.

529. An occurrence of coal [near Somerset, Perry Co., Ohio] which bears evidence of unusual conditions accompanying its deposition: Jour. Geology, vol. 20, no. 4, pp. 316–330, 4 figs., May–June, 1912.

Hynes, Dibrell P.

530. Notes on the geology of the Mina Mexico vein: Econ. Geology, vol. 7, no. 3, pp. 280–286, 2 figs., April–May, 1912.

Describes the general geology, character, and epoch of metallization of the Mina Mexico vein, situated in the Sahuaripa district of Sonora, Mexico.

Iddings, J. P.

Modifications of the quantitative system of classification of igneous rocks. See Cross and others, no. 240.

Illinois State Geological Survey.

531. Provisional geologic map of Illinois. Scale, 1:500,000. 1912.

Contains also an outline of the geological history of Illinois and structure sections.

Ingall, E. D.

532. Bore-hole records (water, oil, etc.): Canada Geol. Survey, Summ. Rept., 1911. pp. 343–345, 1912.

Iowa Geological Survey.

533. Mineral production in Iowa in 1909 and 1910: Iowa Geol. Survey, vol. 21, pp. 1–28, 1912.

Includes notes on the occurrence of various products and a log of a well at Centerville, Iowa.

Irving, John Duer.

534. Geological diagnosis: Econ. Geology, vol. 7, no. 1, pp. 83–86, January, 1912.

Some features of replacement ore bodies and the criteria by which they may be recognized: Canadian Min. Inst., Jour., vol. 14, pp. 395–471, 6 pls., 35 figs., 1912. See no. 549 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 50.

Irwin, D. D.

The planetable in geologic mapping (discussion). See Pelton and Irwin, no. 840.

Jackson, Robert Tracy.

535. Phylogeny of the Echini, with a revision of Paleozoic species: Boston Soc. Nat. Hist., Mem., vol. 7, 491 pp., 76 pls., 258 figs., January, 1912.

Jacobs, E.

536. The coal fields of western Canada: Coal Age, vol. 1, pp. 968–969, May 4, 1912.

Jaggar, T. A., jr.

537. Structure of esker fans experimentally studied: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 746, December 17, 1912.

538. Succession in age of the volcanoes of Hawaii: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 747, December 17, 1912.

Jamison, C. E.

539. The Douglas oil field, Converse County, Wyo.; the Muddy Creek oil field, Carbon County, Wyo.: Wyoming, State Geologist, Ser. B, Bull. 3, 50 pp., 8 pls. (incl. maps and sections) 1912.

540. The Salt Creek oil field, Natrona County, Wyoming: Wyoming, State Geologist, Ser. B, Bull. 4, 75 pp., 16 pls., 1 map, 1912.

Jarvis, Royal P.

541. The valley and mountain iron ores of east Tennessee: Tennessee Geol. Survey, The Resources of Tennessee, vol. 2, no. 9, pp. 326–366, 9 figs., September, 1912. [Also published as Bulletin 2–C.]

Iron deposits in the Tuckahoe district east Tennessee. See Gordon and Jarvis, no. 383.

Jeffrey, Edward C.

542. The history, comparative anatomy, and evolution of the Araucarioxylon type: Am. Acad. Arts and Sci., Proc., vol. 48, no. 13, pp. 531–571, 8 pls. November, 1912.

543. The relations of paleobotany to botany; morphology: Am. Naturalist, vol. 46, pp. 225–238, April, 1912; Abstract, Science, new ser., vol. 35, p. 149, January 26, 1912.

Jennings, E. P.

544. A titaniferous iron-ore deposit in Boulder County, Colorado: Am. Inst. Min. Eng., Bull. no. 70, pp. 1045–1056, 8 figs., October, 1912.

Johannsen, Albert, and others.

545. Petrological abstracts and reviews: Jour. Geology, vol. 20, no. 1, pp. 80–90, January–February, 1912.

546. Petrological abstracts and reviews: Jour. Geology, vol. 20, no. 3, pp. 270–280, April–May, 1912.

547. Petrological abstracts and reviews: Jour. Geology, vol. 20, no. 5, pp. 469–480, July–August, 1912.

Johannsen, O. A.

548. A Tertiary fungus gnat: Am. Jour. Sci., 4th ser., vol. 34, p. 140, 1 fig., August, 1912.

Describes *Mycomya cockerelli* n. sp. from the Miocene shales of Florissant, Colo.

Johnson, Bertrand L.

549. Gold deposits of the Seward-Sunrise region, Kenai Peninsula [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 131–173, 1 pl. (map), 1912.

Includes notes on the stratigraphy of the region.

Johnson, Douglas Wilson.

550. Fixité de la côte atlantique de l'Amerique du Nord: Annales de Géographie, t. 31, pp. 193–212, 6 figs., May 15, 1912.

Discusses evidences offered in proof of recent subsidence of the Atlantic coast, which the author regards as stable in recent times.

551. The stability of the Atlantic coast: Abstract, Science, new ser., vol. 35, p. 318, February 23, 1912. Abstract (with discussion by C. A. Davis, J. W. Spencer, A. C. Lane, H. B. Kümmel): Geol. Soc. America, Bull., vol. 23, no. 4, pp. 739–742, December 17, 1912.

552. The physical history of the Grand Canyon district: Abstract, Science, new ser., vol. 35, p. 199, February 2, 1912.

Johnson, Jay Eliot, and **Tibby**, B. F.

553. Field classification of igneous rocks: Salt Lake Min. Rev., vol. 13, no. 24, pp. 17–19, March 30, 1912.

Johnson, Roswell H.

554. The accumulation of oil and gas in sandstone: Science, new ser., vol. 35 pp. 458–459, March 22, 1912.

555. The necessity for a theory of differential cementing in prospecting for oil (discussion): Econ. Geology, vol. 7, no. 7, pp. 708–709, October–November, 1912.

Johnston, John.

The mineral sulphides of iron. See Allen, Crenshaw, and Johnston, no. 12.

Johnston, Robert A. A.

556. [Report of the] mineralogical division: Canada Geol. Survey, Summ. Rept., 1911, pp. 360–364, 1912.

Johnston, W. A.

557. Geology of Lake Simcoe area, Ontario, Brechin and Kirkfield sheets: Canada Geol. Survey, Summ. Rept., 1911, pp. 253–261, 1912.

Jones, J. Claude.

558. The occurrence of stibnite at Steamboat Springs, Nevada: Science, new ser., vol. 35, pp. 775–776, May 17, 1912.

559. The origin of the anhydrite at the Ludwig mine, Lyon County, Nevada (discussion): Econ. Geology, vol. 7, no. 4, pp. 400–402, June, 1912.

Jones, S. C.

560. Soils of the Hartford quadrangle: Kentucky Geol. Survey, Bull. no. 20, pp. 26–33, 1912.

Joralemon, Ira B.

561. Geology applied to mine examination: Eng. and Min. Jour., vol. 94, pp. 247–249, August 10, 1912.

Katz, F. J.

A geologic reconnaissance of the Iliamna region, Alaska. See Martin and Katz, no. 721.

Geology and coal fields of the lower Matanuska Valley, Alaska. See Martin and Katz, no. 722.

Kay, George F.

562. Nineteenth and twentieth annual reports of the State geologist: Iowa Geol. Survey, vol. 21, pp. ix–xvi, 1 pl. (map), 1912.

Kay, Fred H.

563. The Carlinville oil and gas field: Illinois State Geol. Survey, Extract from Bull. 20, pp. 39–50, 3 pls. (map and sections), 1912.

Keele, Joseph.

564. Notes on tests of clay samples: Canada Geol. Survey, Summ. Rept., 1911, pp. 233–234, 1912.

565. Report on progress of investigation of clay resources: Canada Geol. Survey, Summ. Rept., 1911, pp. 234–239, 1912.

566. Placer gold on Meule Creek, Seigniory of Rigaud-Vaudreuil, Quebec: Canada Geol. Survey, Summ. Rept., 1911, pp. 303–308, 1912.

567. Clay and clay industries of Canada: Applied Science, new ser., vol. 7, no. 2, pp. 39–49, 8 figs., December, 1912.

Preliminary report on the clay and shale deposits of the western provinces. See Ries and Keele, no. 916.

Keith, Arthur.

568. New evidence on the Taconic question: Abstracts, Science, new ser., vol. 35, p. 310, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, pp. 720–721, December 17, 1912.

A Mississippian delta. See Branson, no. 103.

Kellogg, Louise.

569. Pleistocene rodents of California: California, Univ., Dept. Geology, Bull., vol. 7, no. 8, pp. 151–168, 16 figs., December 4, 1912.

Kemp, James F.

570. The mineral springs of Saratoga: New York State Mus., Bull. 159, 79 pp., 3 pls., 6 figs., 1912.

571. The Storm King crossing of the Hudson River by the new Catskill Aqueduct of New York City: Am. Jour. Sci., 4th ser., vol. 34, pp. 1–11, 5 figs., July, 1912.

Presents geologic data derived from borings and tunneling and discusses the depth of the bedded rock under the Hudson and the probable erosive agency. Includes analyses of surface and underground waters.

Geological problems presented by the Catskill Aqueduct of the City of New York: Canadian Min. Inst., Jour., vol. 14, pp. 472–478, 1912. See no. 589 of the bibliography for 1911, U. S. Geol. Survey,, Bull. 524, p. 52.

Keyes, Charles R.

572. Relations of Missouri River loess mantle and Kansan drift sheet: Am. Jour. Sci., 4th ser., vol. 33, pp. 32–34, 1 fig., January, 1912.

573. Deflative scheme of the geographic cycle in an arid climate: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 537–562, 2 figs., November 9, 1912.

574. Toyalané and Lucero; their structure and genetic relations to other plateau plains of deserts: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 713–718, 2 pls., December 14, 1912.

575. A chart of ore deposition: Min. and Sci. Press, vol. 104, p. 763, 1 fig., June 1, 1912.

576. Trunk channels as ore localizers: Eng. and Min. Jour., vol. 94, pp. 1067–1068, December 7, 1912.

577. Sundry provincial and local phases of the general geologic section of Iowa: Abstracts, Iowa Acad. Sci., Proc., vol. 19, pp. 147–151, 1912; Science, new ser., vol. 36, p. 569, October 25, 1912.

578. Nether delimitation of our carbonic rocks: Iowa Acad. Sci., Proc., vol. 19, pp. 153–156, 1912; Abstract, Science, new ser., vol. 36, p. 569, October 25, 1912.

A brief note on the base of the Carboniferous in Iowa.

579. Arid plateau plains as features of eolic erosion: Iowa Acad. Sci., Proc., vol. 19, pp. 157–162, 1912; Abstract, Science, new ser., vol. 36, p. 569, October 25, 1912.

Origin of certain bonanza silver ores of the arid region: Am. Inst. Min. Eng., Trans., vol. 42, pp. 500–517, 1912. See no. 595 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

The agency of manganese in the superficial alteration and secondary enrichment of gold deposits in the United States (discussion): Am. Inst. Min. Eng., Trans., vol. 42, pp. 917–920, 1912. See no. 600 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Kiess, E. E.

580. The after-shocks of the earthquakes of 1903, 1906 ,and 1911 as observed at Mount Hamilton, Cal.: Seism. Soc. America, Bull., vol. 2, no. 1, p. 92, 1912.

Kindle, Edward M.

581. The Onondaga fauna of the Allegheny region: U. S. Geol. Survey, Bull. 508, 144 pp., 13 pls., 1912.

Discusses the occurrence and stratigraphic relations of strata of Onondaga age in New York and southwestward into Virginia and gives systematic descriptions of the fauna.

Kindle, Edward M.—Continued.

582. The unconformity at the base of the Chattanooga shale in Kentucky: Am. Jour. Sci., 4th ser., vol. 33, pp. 120–136, 3 figs., February, 1912.

583. The stratigraphic relations of the Devonian shales of northern Ohio: Am. Jour. Sci., 4th ser., vol. 34, pp. 187–213, 3 figs., August, 1912.

584. Note on a ripple-marked limestone: Ottawa Naturalist, vol. 26, no. 9, pp. 108–110, 1 pl., December, 1912.

Describes a Devonian limestone showing ripple marks on Snake Island, Lake Winnipegosis, northern Manitoba.

King, Louis Vessot.

585. On the limiting strength of rocks under conditions of stress existing in the earth's interior: Jour. Geology, vol. 20, no. 2, pp. 119–138, 2 figs, February–March, 1912.

Kirk, Charles T.

586. Conditions of mineralization in the copper veins at Butte, Montana: Econ. Geology, vol. 7, no. 1, pp. 35–82, 2 figs., January, 1912.

Kirkpatrick, F. A., and **Nelson**, Wilbur A.

587. Tests on the clays of Henry County: Tennessee State Geol. Survey, The Resources of Tennessee, vol. 2, no. 11, pp. 406–423, November, 1912.

Kirkpatrick, R.

588. On the stromatoporoids and Eozoon: Annals and Mag. Nat. Hist., 8th ser., vol. 10, pp. 341–347, 2 pls., September, 1912.

589. On the structure of stromatoporoids and of Eozoon: Annals and Mag. Nat. Hist., 8th ser., vol. 10, pp. 446–460, 2 pls., 3 figs., October, 1912.

Kittl, Ernst.

590. Die Triasfossilien vom Heureka Sund: Norwegian Arctic Expedition in the "Fram" (Second), Rept., no. 7., 44 pp., 3 pls. (published by Videnskabs-Selskabet i Kristiania), 1907.

Describes Triassic fossils from the borders of Eureka Sound, Arctic America.

Klein, A. A.

Die optischen Eigenschaften einiger Bleisilikate. See Kraus and others, no. 610.

Knapp, I. N.

591. Value of geology in the petroleum industry: Min. and Eng. World, vol. 36, p. 412, February 17, 1912.

592. Natural gas, with incidental reference to other bitumens: Franklin Inst., Jour., vol. 174, nos. 5 and 6, pp. 477–498, 639–662, 16 figs., November and December, 1912.

Knight, Cyril W.

Geology of the Cobalt district, Ontario, Canada (discussion): Am. Inst. Min. Eng., Trans., vol. 42, pp. 924–926, 1912. See no. 615 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Knight, Wilbur C.

593. The Green River, Utah, oil field: Salt Lake Min. Rev., vol. 13, no. 22, pp. 11–14, 5 figs., February 29, 1912.

Includes notes on the geology of the field.

Knopf, Adolph.

594. The Eagle River region, southeastern Alaska: U. S. Geol. Survey, Bull. 502, 61 pp., 5 pls. and 3 figs. (including maps), 1912.

Describes the physiographic features and general geology, the stratigraphy and geologic structure, and the gold deposits.

595. The Sitka mining district, Alaska: U. S. Geol. Survey, Bull. 504, 32 pp., 4 figs., 1 map, 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 6, p. 161, March 19, 1912.

Describes the general geology, the gold-ore deposits, the nonmetallic resources, chiefly gypsum, and the mining developments.

596. Geology of the Berners Bay region, Alaska: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 3, pp. 84–85, February 4, 1912.

597. The magmatic sulphide ore body at Elkhorn, Montana: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 358–359, August 19, 1912.

Knopf, Adolph, and **Umpleby**, J. B.

598. Recent literature on economic geology: Econ. Geology, vol. 7, no. 3, pp. 303–310, April–May, 1910.

599. Recent literature on economic geology: Econ. Geology, vol. 7, no. 4, pp. 404–413, June, 1912.

600. Recent literature on economic geology: Econ. Geology, vol. 7, no. 6, pp. 607–615, September, 1912.

Knowlton, Frank Hall.

601. The relations of paleobotany to geology: Am. Naturalist, vol. 46, pp. 207–215, April, 1912; Abstract, Science, new ser., vol. 35, p. 148, January 26, 1912.

Knox, H. H.

602. Criteria for replacement ore bodies (discussion): Econ. Geology, vol. 7, no. 3, pp. 295–297, April–May, 1912.

Koch, I. P., and **Wegener**, A.

603. Die glaciologischen Beobachtungen der Danmark-Expedition: Meddelelser om Grönland, Bd. 46, pp. 1–77, 98 pls. and figs., 5 pls.)maps), 1912.

Describes glaciers of northeastern Greenland.

Koenig, George Augustus.

604. New observations in chemistry and mineralogy: Acad. Nat. Sci. Philadelphia, Jour., 2d ser., vol. 15, pp. 405–426, 1 pl., 1912.

Koenigsberger, Joh.

605. Transformations and chemical reactions in their application to temperature measurements of geological occurrences (translated by Joseph A. Ambler): Econ. Geology, vol. 7, no. 7, pp. 676–707, 7 figs., October–November, 1912.

Komorowicz, Maurice v.

606. Vulkanologische Studien auf einigen Inseln des Atlantischen Oceans. 191 pp., 29 pls., 80 figs. Stuttgart, E. Schweizerbartsche Verlagsbuchhandlung, 1912.

Studies on Iceland and other volcanic islands of the Atlantic Ocean. Includes discussion of the volcanoes of the Hawaiian Islands.

Kramm, H. E.

607. Geology of Harrison Gulch, in Shasta County, California: Am. Inst. Min. Eng., Bull., no. 67, pp. 709–715, 2 figs., July, 1912; Trans., vol. 43, pp. 233–239, 2 figs., 1913.

608. Gypsum of New Brunswick: Canada Geol. Survey, Summ. Rept., 1911, pp. 322–327, 1912.

Kraus, E. H., and **Youngs**, L. J.

609. Ueber die Aenderungen des optischen Achsenwinkels in Gips mit der Temperatur [Variation of the optic angle of gypsum with temperature]: Neues Jahrb., Bd. 1, H. 3, pp. 123–146, 7 figs., August 27, 1912; Abstract, Science, new ser., vol. 35, p. 313, February 23, 1912; Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, pp. 726–727, December 17, 1912.

Kraus, E. H., **Cooper**, H. C., and **Klein**, A. A.

610. Die optischen Eigenschaften einiger Bleisilikate: Centralbl. Mineralogie, no. 10, pp. 289–295, 1 fig. May 15, 1912.

Describes the optical properties of some lead silicates.

Kümmel, Henry B.

611. Annual administrative report of the state geologist for the year 1911: New Jersey Geol. Survey, Bull. 6, 82 pp., 1912.

Includes summaries of investigations carried on by the survey, various data relating to the geology of New Jersey, and an explanation of a method of note-taking for field observations.

612. The mineral industry of New Jersey for 1911: New Jersey Geol. Survey, Bull. 7, 37 pp., 1912.

A Mississippian delta. See Branson, no. 103.

Kunz, George F.

613. On the occurrence of opal in northern Nevada and Idaho: Abstract, New York Acad. Sci., Annals, vol. 21, pp. 214–215, 1912.

Lachmann, R.

614. Ekzeme als geologische Chronometer: Deutsch. geol. Ges., Zeits., Monatsber., no. 12, pp. 553–562, 5 figs., 1912.

The eczeme [upgrowth of salt beds] as a geologic thermometer. The discussion is based in part on the salines of Louisiana and Texas.

La Forge, Laurence.

615. Is there a Permian series?: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, pp. 106–107, February 19, 1912.

Considers the Permian to be part Carboniferous and part Triassic.

Lahee, Frederick H.

616. Crescentic fractures of glacial origin: Am. Jour. Sci., 4th ser., vol. 33, pp. 41–44, 2 figs., January, 1912.

617. Relations of the degree of metamorphism to geological structure and to acid igneous intrusion in the Narragansett Basin, Rhode Island: Am. Jour. Sci., 4th ser., vol. 33, pp. 249–262, 354–372, 447–469, 40 figs., March, April, and May, 1912.

618. A new fossiliferous horizon on Blueberry Mountain in Littleton, New Hampshire: Science, new ser., vol. 36, pp. 275–276, August 30, 1912.

Lakes, Arthur, sr.

619. Geology of the Breckenridge placers [Summit. Co., Colo.]: Mines and Minerals, vol. 32, pp. 430–433, 4 figs., February, 1912.

620. Snowslides in mining districts of British Columbia: Min. and Eng. World, vol. 36, pp. 505–507, March 2, 1912.

621. Effects of landslides in mining regions: Min. and Eng. World, vol. 36, pp. 861–862, 3 figs., April 20, 1912.

622. Relation of shearage zones and mineral veins: Min. and Eng. World, vol. 37, pp. 1001–1002, 2 figs., November 30, 1912.

623. Depth and continuity of fissure veins and their ore: Min. and Eng. World, vol. 37, pp. 1095–1097, 1 fig., December 14, 1912.

Lakes, Arthur, jr.

624. Present outlook and conditions in the Klondike region: Min. and Sci. World, vol. 36, p. 916, April 27, 1912.

Includes notes on the geology and the occurrence of the gold ores.

Lambe, Lawrence M.

625. Presidential address: The past vertebrate life of Canada: Roy. Soc. Canada, Proc. and Trans., 3d ser., vol. 5, sec. 4, pp. 3–15, 1912.

626. [Report of the] Paleontological division; vertebrates: Canada Geol. Survey, Summ. Rept., 1911, pp. 346–351, 1912.

Lane, Alfred C.

627. The Keweenaw series of Michigan: Michigan Geol. and Biol. Survey, Pub. 6 (Geol. ser. 4). 2 vols., 983 pp., 15 pls. (incl. maps), 69 figs., 1911.

628. Diamond drilling at Point Mamainse, Province of Ontario; with introduction by Alfred W. G. Wilson: Canada, Dept. Mines, Mines Branch, Bull. no. 6, 59 pp., 5 pls., 1 fig., 1 map, 1912.

Describes the general geologic structure of the district and discusses the occurrence of copper ores.

629. Unexplored parts of the copper range of Keweenaw Point (with discussion): Lake Superior Min. Inst., Proc., vol. 17, pp. 127–143, 1912.

630. Aragonite coating gravel pebbles: Science, new ser., vol. 36, pp. 81–82, July 19, 1912.

631. Dark scale of hardness: Abstracts, Science, new ser., vol. 35, p. 312, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 725, December 17, 1912.

632. Demonstration of relative refraction: Abstracts, Science, new ser., vol. 35, p. 312, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 725, December 17, 1912.

Native copper deposits: Canadian Min. Inst., Jour., vol. 14, pp. 316–322 (discussion, pp. 322–325), 1912. See no. 662 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 57.

Larsen, Esper S.

633. The mineral sulphides of iron; crystallographic study: Am. Jour. Sci., 4th ser., vol. 33, pp. 218–236, 9 figs., March, 1912.

Larsen, E. S., and **Schaller**, W. T.

634. Hinsdalit, ein neues Mineral: Zeits. Krystal., Bd. 50, H. 2, pp. 101–105, 5 figs., 1912.

Describes the occurrence, characters, and composition of a new mineral, named hinsdalite, from the San Cristobal quadrangle, Colorado.

Latimer, J. F.

635. Origin of petroleums: Canadian Min. Jour., vol. 33, pp. 4–5, January 1, 1912.

Lawson, Andrew C.

636. The geology of Steeprock Lake, Ontario. Canada Geol. Survey. Mem. no. 28, pp. 7–15, 1912.

637. The Archean rocks of Rainy Lake: Canada Geol. Survey, Summ. Rept., 1911, pp. 240–243, 1 pl. (map), 1912.

638. The recent fault scarps at Genoa, Nevada: Seism. Soc. America, Bull., vol. 2, no. 3, pp. 193–200, 2 pls., 1 fig., September, 1912.

639. Fanglomerate, a detrital rock at Battle Mountain, Nevada: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 72, March 14, 1912.

640. Section of the Shinarump: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 74, March 14, 1912.

641. Geology of the Nevada Hills: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 74, March 14, 1912.

642. Types of ore deposits—a review: Min. and Sci. Press, vol. 104, pp. 199–201, February 3, 1912.

Layman, F. E.

Portland-cement resources of Illinois. See Bleininger and others, no. 84.

Leach, W. W.

643. Geology of Blairmore map area, Alberta: Canada Geol. Survey, Summ. Rept., 1911, pp. 192–200, 1912.

Lee, Charles H.

644. An intensive study of the water resources of a part of Owens Valley, California: U. S. Geol. Survey, Water-Supply Paper 294, 135 pp., 30 pls., 8 figs., 1912.

Lee, Montrose L.

645. A geological study of the Elisa mine, Sonora, Mexico: Econ. Geology, vol. 7, no. 4, pp. 324–339, 8 figs., June, 1912.

Describes the general geology of the area, the fault system, the contact metamorphism, and the mineralization.

Lee, Willis Thomas.

646. The Tijeras coal field, Bernalillo County, New Mexico: U. S. Geol. Survey, Bull. 471, pp. 574–578, 1 pl. (map), 1912.

647. Coal fields of Grand Mesa and the West Elk Mountains, Colorado: U. S. Geol. Survey, Bull. 510, 237 pp., 21 pls., 37 figs. (incl. maps and sections), 1912.

Describes the stratigraphy and geologic structure, the occurrence, character, and relations of the coal beds, and the quality of the coal.

648. Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 571–686, 5 figs., November 26, 1912.

649. Correlation of rocks in the isolated coal fields around the southern end of the Rocky Mountains in New Mexico: Abstract, Science, new ser., vol. 35, p. 311, February, 1912.

650. Extinct volcanoes of northeast New Mexico: Am. Forestry, vol. 18, no. 6, pp. 357–365, 7 figs., June, 1912.

Describes the occurrence, form, relative age, and other features of cones, lava fields, and other remains of volcanic activity.

Leith, C. K.

651. Use of geology in iron ore exploration: Econ. Geology, vol. 7, no. 7, pp. 662–675, October–November, 1912.

Iron-ore reserves of Michigan. See no. 1127.

Leith, C. K., and **Mead,** W. J.

652. Metamorphic studies: Jour. Geology, vol. 20, no. 4, pp. 353–361, May–June, 1912.

Discusses the metamorphic cycle.

Origin of the iron ores of central and northeastern Cuba: Am. Inst. Min. Eng., Trans., vol. 42, pp. 90–102, 1 fig., 1912. See no. 677 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Lenher, Victor.

653. The transportation and deposition of gold in nature: Econ. Geology, vol. 7, no. 8, pp. 744–750, December, 1912.

Leonard, A. G.

654. Description of the Bismarck quadrangle [North Dakota]: U. S. Geol. Survey, Geol. Atlas U. S., Bismarck folio (no. 181), 8 pp., 2 pls. (maps), 1 fig., 1912; field edition, 58 pp., 2 folded maps (in pocket), 1 fig., 1912.

Describes the topography, the character, occurrence, and relations of Cretaceous, Tertiary, and Quaternary formations, the geologic history, and the mineral resources.

LeRoy, O. E.

655. The geology and ore deposits of Phoenix, Boundary district, British Columbia: Canada, Geol. Survey, Mem. no. 21, 110 pp., 7 pls., 18 figs., 2 maps, 1912.

656. Geology of Nelson map area [West Kootenay district, British Columbia]: Canada Geol. Survey, Summ. Rept., 1911, pp. 139–157, 1 pl. (map), 6 figs., 1912.

Lett, Stephen J.

657. Persistence of ore in depth: Min. and Sci. Press, vol. 105, pp. 801–802, December 21, 1912.

Leverett, Frank.

658. Surface geology and agricultural conditions of the southern peninsula of Michigan: Michigan Geol. and Biol. Survey, Pub. 9, Geol. Ser. 7, 144 pp., 15 pls. (incl. maps), 16 figs., 1912.

659. Postglacial erosion and oxidation (discussion): Geol. Soc. America, Bull., vol. 23, p. 295, June 1, 1912.

660. Glacial investigations in Minnesota in 1911: Abstract, Science, new ser., vol. 35, p. 315, February 23, 1912; Abstract (with discussion by J. B. Tyrrell and Warren Upham), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 732–735, December 17, 1912.

Lewis, J. Volney.

661. Notes on the paragenesis of the zeolites: Abstract, Science, new ser., vol. 35, p. 313, February 23, 1912; Abstract (with discussion by A. C. Lane and F. R. Van Horn), Geol. Soc. America, Bull., vol. 23, no. 4, p. 727, December 17, 1912.

Lincoln, Francis Church.

662. Certain natural associations of gold (discussion): Econ. Geology, vol. 7, no. 1, pp. 87–88, January, 1912.

663. Gold deposits of Gibbonsville, Idaho: Min. and Sci. Press, vol. 105, pp. 47–49, July 13, 1912.

Lindeman, E.

664. The iron-ore deposits along the Central Ontario railway: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 95–100, 1912.

665. Calabogie iron-bearing district [Renfrew County, Ontario]: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 101–103, 1912.

666. Magnetometric survey of a nickeliferous pyrrhotite deposit in the Sudbury district: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 103–104, map, 1912.

Lindgren, Waldemar.

667. Geologic introduction to The mining districts of the western United States, by James M. Hill: U. S. Geol. Survey, Bull. 507, pp. 5–43, 1 fig. (map), 1912.

Discusses the geologic distribution and relation to structural conditions of ore deposits in Western States.

668. The nature of replacement: Econ. Geology, vol. 7, no. 6, pp. 521–535, September, 1912.

669. The bonanza of National, Nevada: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, pp. 107–108, February 19, 1912.

Mineral resources of the United States, 1911: Platinum and allied metals. See no. 1127.

Lines, Edwin F.

670. The stratigraphy of Illinois with reference to Portland-cement materials: Illinois State Geol. Survey, Bull. no. 17, pp. 59–76, 1912.

Portland-cement resources of Illinois. See Bleininger and others, no. 84.

Linton, Robert.

671. Geology of Ocampo district, Mexico: Eng. and Min. Jour., vol. 94, pp. 653–655, 3 figs., October 5, 1912.

Livingston, D. C.

672. Mining methods at Nacozari, Sonora, Mexico: Am. Inst. Min. Eng., Bull., no. 69, pp. 1009–1015, 2 figs., September, 1912.

Gives notes on the character and occurrence of the copper ores.

Locke, Augustus.

673. The geology of the Tonopah mining district, Nevada: Am. Inst. Min. Eng., Bull., no. 62, pp. 217–226, 4 figs., February, 1912; Trans., vol. 43, pp. 157–166, 4 figs., 1913.

674. The abnormal temperatures on the Comstock lode (discussion): Econ. Geology, vol. 7, no. 6, pp. 583–587, 2 figs., September, 1912.

675. Tuolumne Table Mountain [near Jamestown, Cal.]: Min. and Sci. Press, vol. 105, p. 85, July 20, 1912.

Gives a section showing the relations of the bedded rocks.

676. The ore deposits of Goldfield [Nevada]: Eng. and Min. Jour., vol. 94, pp. 797–802, 843–849, 7 figs., October 26 and November 2, 1912.

Louderback, George Davis.

677. Pseudostratification in Santa Barbara County, California: California, Univ., Dept. Geology, Bull., vol. 7, no. 2, pp. 21–38, 4 pls., May 25, 1912.

678. Proceedings of the twelfth annual meeting of the Cordilleran section of the Geological Society of America, held at Berkeley, California, March 31 and April 1, 1911: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 69–76, March 14, 1912.

679. Some general features of the Miocene of the southern coast range region of California: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 72, March 14, 1912.

Loughlin, G. F.

680. The gabbros and associated rocks at Preston, Connecticut: U. S. Geol. Survey, Bull. 492, 158 pp., 14 pls., 18 figs., 1912. Abstract (by C. E. Siebenthal), Washington Acad. Sci., Jour., vol. 2, no. 16, pp. 408–410, October 4, 1912.

Loughlin, G. F., and **Goodspeed**, G. E., jr.

681. Recent literature on economic geology: Econ. Geology, vol. 7, no. 1, pp. 96–109, January, 1912.

Loveman, M. H.

682. Geology of the Miami copper mine [near Globe, Arizona]: Min. and Sci. Press, vol. 105, pp. 146–148, 1 fig., August 3, 1912.

Lowe, E. N.

683. Examination of iron ore deposits in Marshall and Benton counties: Mississippi State Geol. Survey, 23 pp., 1912.

Lucas, A. F.

684. Geology of the sulphur and sulphur oil deposits of the coastal plain: Jour. Ind. and Eng. Chem., vol. 4, no. 2, pp. 140–143, February, 1912.

685. The dome theory of the coastal plain: Science, new ser., vol. 35, pp. 961–964, June 21, 1912.

Lull, Richard Swann.

686. The evolution of the Ceratopsia: Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 771–777, 1 fig., Cambridge, U. S. A., 1912.

687. Ten years' progress in vertebrate paleontology; Cretaceous dinosaurs; Geol. Soc. America, Bull., vol. 23, no. 2, pp. 208–212, June 1, 1912.

688. The life of the Connecticut Trias: Am. Jour. Sci., 4th ser., vol. 33, pp. 397–422, 5 figs., May, 1912.

Lupton, Charles T.

689. The Deep Creek district of the Vernal coal field, Uinta County, Utah: U. S. Geol. Survey, Bull. 471, pp. 579–594, 1 pl., 1 fig. (maps), 1912.

690. The Blacktail (Tabby) Mountain coal field, Wasatch County, Utah: U. S. Geol. Survey, Bull. 471, pp. 595–628, 2 pls. (map and sections), 1912.

691. Notes on the geology of the San Rafael Swell, Utah: Washington Acad. Sci., Jour., vol. 2, no. 7, pp. 185–188, April 7, 1912.

McCallum, A. L.

692. Scheelite in Nova Scotia: Nova Scotian Inst. Sci., Proc. and Trans., vol. 12, pt. 3, pp. 250–252, March, 1912.

McCaskey, H. D.

693. Quicksilver: U. S. Geol. Survey, Min. Res. U. S., 1911, pt. 1, pp. 889–921, 1912.

Mineral resources of the United States, 1911: Metals and metallic ores in 1910 and 1911; gold and silver; gold, silver, copper, lead, and zinc in the Western States (mine production); gold, silver, copper, lead, and zinc in the Eastern States (mine production); quicksilver. See no. 1127.

McConnell, R. G.

694. Observatory Inlet, British Columbia: Canada Geol. Survey, Summ. Rept., 1911, pp. 41–50, 2 pls. (maps), 1912.

Gives notes on the geology and the mineral resources of the area in the vicinity of Observatory Inlet.

695. Salmon River district: Canada Geol. Survey, Summ. Rept., 1911, pp. 50–56, 1 pl. (map), 1912.

Describes the general geology and mineralization of the Salmon River district, British Columbia.

696. Portland Canal district: Canada Geol. Survey, Summ. Rept., 1911, pp. 56–71, 1912.

Describes the general geology and the mineral deposits of the Portland Canal mining district, British Columbia.

MacDonald, Donald F.

697. Heated areas in Culebra cut [Panama Canal Zone]: Canal Record, vol. 5, pp. 225–226, March 6, 1912.

Explains the heat generated in certain strata as due to the oxidation of pyrite.

698. Heating of local areas of ground in Culebra cut, Canal Zone: Science, new ser., vol. 35, pp. 701–702, May 3, 1912.

699. Coal deposits on the Canal Zone [Panama]: Canal Record, vol. 5, p. 255, April 3, 1912.

Gives data on the geology of the Canal Zone. No deposits of coal of commercial value occur.

700. Geology of Culebra cut [Panama Canal]: Min. and Sci. Press, vol. 105, p. 726, December 7, 1912.

McDonald, P. B.

701. History of the Cascade iron range of Michigan: Min. and Eng. World, vol. 37, pp. 902–905, 4 figs., November 16, 1912.

MacDonald, W. T.

702. The San Juan oil field, Utah: Western Eng., vol. 1, no. 1, pp. 37–46, 9 figs., April, 1912.

Macdougal, Daniel Trembly.

703. Some physical and biological features of North American deserts: Scottish Geog. Mag., vol. 28, no. 9, pp. 449–456, September, 1912.

Mackenzie, George C.

704. The magnetic iron sands of Natashkwan, County of Saguenay, Province of Quebec: Canada, Dept. Mines, Mines Branch, 49 pp., 22 pls., 3 maps, 9 figs., 1912.

McLaren, Alex.

705. Gold and rare metal mining near Llano, Texas: Salt Lake Min. Rev., vol. 14, no. 3, pp. 11–13, 2 figs., May 15, 1912.

Maclaren, Malcolm.

706. Persistence of ore in depth: Min. and Sci. Press, vol. 105, pp. 534–535, 4 figs., October 26, 1912.

MacLean, T. A.

707. Notes on the Porcupine gold region, Ontario: Min. Soc. Nova Scotia, Jour., vol. 17, pp. 82–93, 1912.

McLeish, John.

708. Annual report on the mineral production of Canada during the calendar year 1910: Canada, Dept. Mines, Mines Branch, 328 pp., 1912.

McMillan, J. G.

709. Report on the geology of the area along the T. &. N. O. Railway, trial line between Gowganda and Porcupine. 24 pp., 4 pls., map. Toronto, printed by order of the Legislative Assembly of Ontario, 1912.

McNair, S. S.

710. What is a stratified rock?: Eng. and Min. Jour., vol. 94, p. 147, July 27, 1912.

Maddren, A. G.

711. The Ruby placer district [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 287–296, 1 pl. (map), 1912.

Gives notes on the stratigraphy and the occurrence of placer gold.

712. Geologic investigations along the Canada-Alaska boundary: U. S. Geol. Survey, Bull. 520, pp. 297–314, 1912.

Madison, H. M.

713. The water supply of southwest Texas. 24 pp., illus. [Private publication.] Copyright, 1912.

Includes notes on the geology and the underground waters.

Malloch, G. S.

714. Notes on the Groundhog coal basin, Skeena district, B. C.: Canadian Min. Inst., Trans., vol. 15, pt. 1, pp. P 21–25, 1912.

715. Reconnaissance on the upper Skeena River, between Hazelton and the Groundhog coal field, British Columbia: Canada Geol. Survey, Summ. Rept., 1911, pp. 72–90, 1 pl. (map), 1912.

Mangum, A. W., and **Neill**, N. P.

716. Soil survey of parts of Spencer and Warrick, and Scott counties: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 335–381, 2 pls. (maps), 2 figs., 1912.

Mann, Charles J.

Soil survey of Greene County. See Tharp and Mann, no. 1074.

Mansfield, G. R.

The Bannock overthrust. See Richards and Mansfield, no. 903.

Marean, Herbert W.

717. Soil survey of Posey County: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 382–407, 1 pl. (map), 1 fig., 1912.

Martin, Bruce.

718. Fauna from the type locality of the Monterey series in California: California, Univ., Dept. Geology, Bull., vol. 7, no. 7, pp. 143–150, December 4, 1912.

Describes the beds at this locality, gives lists of the species at different horizons, and discusses the correlation with other exposures of strata supposed to be of the same age.

Martin, D. S.

719. [On schernikite and winchellite, two new varieties of minerals]: Abstract, New York Acad. Sci., Annals, vol. 21, pp. 189–190, 1912.

Martin, G. C.

720. Mesozoic stratigraphy of Alaska: Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, pp. 724–725, December 17, 1912.

Martin, G. C., and **Katz**, F. J.

721. A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey, Bull. 485, 138 pp., 9 pls., 20 figs., 2 inserts, 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 9, pp. 224–225, May 4, 1912.

722. Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey, Bull. 500, 98 pp., 19 pls. (incl. maps), 12 figs., 1912; Abstract, Washington Acad. Sci., Jour. vol. 2, no. 9, pp. 225–226, May 4, 1912.

Martin, Lawrence.

723. Gletscheruntersuchungen längs der Küste von Alaska: Petermanns Mitt., Jg. 58, pp. 78–81, 3 pls., 1 map, August, 1912.

Describes glaciers along the coast of Alaska.

The earthquakes at Yakutat Bay, Alaska, in September, 1899. See Tarr and Martin, no. 1066.

Glacial deposits of the continental type in Alaska. See Tarr and Martin, no. 1067.

Maryland Geological and Economic Survey.

724. Guide to the State mineral exhibit illustrating the mineral resources and industries, geology, and modern methods of road construction installed by the Maryland Geological Survey in the Old Hall of Delegates at Annapolis, Md. 61 pp., illus. Baltimore, 1912.

Includes various information in regard to the geology of Maryland.

Mather, Kirtley F.

The evidence of three distinct glacial epochs in the Pleistocene history of the San Juan Mountains, Colorado. See Atwood and Mather, no. 32.

Matson, G. C.

Mineral resources of the United States, 1911: Mineral waters. See no. 1127.

Matteson, W. G.

725. Geologic structure of silver districts: Mines and Minerals, vol. 32, pp. 358–360, 2 figs., January, 1912.

726. Minerals common to silver deposits: Mines and Minerals, vol. 32, pp. 438–440, 2 figs., February, 1912.

727. Genesis of silver deposits: Mines and Minerals, vol. 32, pp. 504–506, March, 1912.

Matthes, François E.

728. Sketch of Yosemite National Park and an account of the origin of the Yosemite and Hetch Hetchy valleys. 47 pp., 23 figs. U. S. Dept. of the Interior, Office of the Secretary, Washington, 1912.

729. Undescribed glaciers of Mt. Rainier: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 12, pp. 297–298, June 19, 1912.

Matthew, G. F.

730. Were there climatic zones in Devonian time?: Roy. Soc. Canada, Proc. and Trans., 3d ser., vol. 5, sec. 4, pp. 125–153, 1912.

Matthew, W. D.

731. Ten years' progress in vertebrate paleontology: Carnivora and Rodentia: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 181–187, June 1, 1912.

732. The new four-toed horse skeleton: Am. Mus. Jour., vol. 12, no. 5, p. 186, 1 fig., May, 1912.

Gives notes upon Eocene horses.

733. New dinosaurs for the American Museum: Am. Mus. Jour., vol. 12, no. 6, p. 219, October, 1912.

734. The ancestry of the edentates as illustrated by the skeleton of Hapalops, a Tertiary ancestor of the ground sloths: Am. Mus. Jour., vol. 12, no. 8, pp. 300–303, 2 figs., December, 1912.

735. Climate and evolution: Abstract, New York Acad. Sci., Annals, vol. 21, pp. 190–191, 1912.

Discusses the geographic distribution of animals with relation to the permanency of oceanic basins and continental areas.

Maury, Carlotta Joaquina.

736. A contribution to the paleontology of Trinidad: Acad. Nat. Sci. Philadelphia, Jour., 2d ser., vol. 15, pp. 23–112, 9 pls., 1912.

Discusses the age and relations of Tertiary faunas and the correlation of the beds in which they are found, and gives systematic descriptions of new species, mainly Mollusca.

737. A contribution to the paleontology of Trinidad: Abstract, Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 1, pp. 132–134, 1912.

Maynard, T. Poole.

738. A report on the limestones and cement materials of north Georgia: Georgia Geol. Survey, Bull. no. 27, 293 pp., 22 pls., 6 figs., geol. map, 1912.

Mead, W. J.

739. Some geological short-cuts: Econ. Geology, vol. 7, no. 2, pp. 136–144, 2 pls., February–March, 1912.

Presents methods for the conversion of rock analyses into terms of minerals.

Metamorphic studies. See Leith and Mead, no. 652.

Mehl, Maurice G.

740. *Pantylus cordatus* Cope: Jour. Geology, vol. 20, no. 1, pp. 21–27, 2 figs., 1912.

Describes another specimen (skull) of this species from the Wichita division of the Red Beds of Baylor County, Texas.

741. *Murænosaurus? reedii* sp. nov. and *Tricleidus? laramiensis* Knight, American Jurassic plesiosaurs: Jour. Geology, vol. 20, no. 4, pp. 344–352, 3 figs., May–June, 1912.

Meinzer, O. E.

742. Ground water in Juab, Millard, and Iron counties, Utah: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 9, p. 226, May 4, 1912.

743. Geology and water resources of Estancia Valley, New Mexico, with notes on ground-water conditions in adjacent parts of central New Mexico: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 9, pp. 226–227, May 4, 1912.

Meinzer, O. E.—Continued.

744. The development of a typical bolson in the Southwest: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 357–358, August 19, 1912.

Underground water resources of Iowa. See Norton and others, no. 800.

Merriam, John C.

745. The fauna of Rancho La Brea; Part II, Canidæ: California, Univ., Mem., vol. 1, no. 2, pp. 215–272, 5 pls., 43 figs., 1912.

746. Recent discoveries of Carnivora in the Pleistocene of Rancho La Brea: California, Univ., Dept. Geology, Bull., vol. 7, no. 3, pp. 39–46, 10 figs., September 12, 1912.

747. Ten years' progress in vertebrate paleontology; Marine reptiles: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 221–223, June 1, 1912.

Merrill, F. J. H.

748. The Spring Valley oil field in southwestern Wyoming: Min. and Sci. Press, vol. 104, pp. 163–165, 2 figs., January 27, 1912.

Merrill, George P.

749. A second meteoric find from Scott County, Kansas: U. S. Nat. Mus., Proc., vol. 42, pp. 295–296, 1 pl., June 15, 1912.

750. A recent meteorite fall near Holbrook, Navajo County, Arizona: Smithsonian Misc. Coll., vol. 60, no. 9, 4 pp., November 21, 1912.

751. A newly-found meteoric iron from Perryville, Perry County, Missouri: U. S. Nat. Mus., Proc., vol. 43, pp. 595–597, 2 pls., December 31, 1912.

Mertie, J. B., jr.

Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River. See Prindle and Mertie, no. 869.

Merwin, H. E.

The sulphides of zinc, cadmium, and mercury; their crystalline forms and genetic conditions; microscopic study. See Allen and Crenshaw, no. 11.

Meuche, A. H.

752. The development of the copper mines of Lake Superior and their geological relations: Michigan Geol. and Biol. Survey, Pub. 6 (Geol. ser. 4), vol. 2, pp. 887–931, 8 figs., 1911.

México, Instituto Geológico.

753. Estación seismológica central; catálogo de los microseísmos registrados durante el año de 1911: Mexico, Inst. Geol., Parerg., t. 4, no. 1, pp. 33–85, 1912.

Gives a list of earthquake shocks and microseisms recorded in the seismologic station at Tacubaya, D. F., Mexico.

Michael, Graham J.

Subject index of the bibliography of the geology, paleontology, mineralogy, petrology and mineral resources of Oregon. See Henderson and Winstanley, no. 445.

Michaud, Gustavo.

754. Nota sobre el epicentro del terremoto del 30 de diciembre de 1888: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 9–15, 5 figs., 1912.

Gives data on the earthquake in Costa Rica of December 30, 1888.

Informe sobre el terremoto de Toro Amarillo, Grecia. See Alfaro, Michaud, and Biolley, no. 8.

Middleton, Jefferson.

755. Clay products and clay in the South: Manufacturers Record, vol. 61, no. 7, pt. 2, pp. 65–66, February 22, 1912.

Miller, A. M.

756. Coals of the lower measures along the western border of the eastern coal field: Kentucky Geol. Survey, Bul. no. 12, 83 pp., 7 pls. (maps and sections), 1910 [distributed 1912 or 1913].

Miller, Benjamin Le Roy.

757. The mineral pigments of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Rept. no. 4, 101 pp., 29 pls., 9 figs., 1911.

758. Description of the Choptank quadrangle [Maryland]: U. S. Geol. Survey, Geol. Atlas U. S., Choptank folio (no. 182), 8 pp., 2 pls. (maps), 3 figs., 1912; field edition, 64 pp., 2 folded maps (in pocket), 3 figs., 1912.

Describes the topography, the stratigraphy (Tertiary and Quaternary), the geologic history, and the mineral resources.

759. The geology of the graphite deposits of Pennsylvania: Econ. Geology, vol. 7, no. 8, pp. 762–777, December, 1912.

The physiography and geology of the Coastal Plain province of Virginia. See Clark and Miller, no. 192.

The Coastal Plain of North Carolina; the Tertiary formations. See Clark and others, no. 193.

Miller, Benjamin L., and Stephenson, L. W.

The Coastal Plain of North Carolina: Bibliography. See Clark and others, no. 193.

Miller, G. W.

760. The original source of metalliferous ores: Min. and Eng. World, vol. 36, pp. 515–516, March 2, 1912.

761. Two phases in the genesis of ore deposits: Min. and Eng. World, vol. 36, pp. 1095–1097, 1151–1152, May 25 and June 1, 1912.

Miller, Loye Holmes.

762. Contributions to avian paleontology from the Pacific coast of North America: California, Univ., Dept. Geology, Bull., vol. 7, no. 5, pp. 61–115, October 12, 1912.

Miller, Willet G.

Report of the Commission appointed to investigate Turtle Mountain, Frank, Alberta. See Daly and others, no. 257.

Miller, Willet G., and others.

763. Reports on the District of Patricia recently added to the Province of Ontario: Ontario, Bur. Mines, Rept. 1912, vol. 21, pt. 2, 216 pp., pls., figs., maps, 1912.

A general account of the District of Patricia, including geologic features. Earlier reports on various parts of the area by Robert Bell, D. B. Dowling, Alfred W. G. Wilson, Charles Camsell, A. P. Low, William McInnes, W. J. Wilson, and Owen O'Sullivan are reproduced.

Miller, William J.

764. The garnet deposits of Warren County, New York: Econ. Geology, vol. 7, no. 5, pp. 493–501, 1 fig., August, 1912.

765. Contact action of gabbro on granite in Warren County, New York: Science, new ser., vol. 36, pp. 490–492, October 11, 1912.

Underground water resources of Iowa. See Norton and others, no. 800.

Milner, W. C.

766. History of albertite: Min. Soc. Nova Scotia, Jour., vol. 17, pp. 62–69, 1912.

Mississippi Geological Survey Commission.

767. Third biennial report, June 30, 1909–June 30, 1911. 14 pp., no date [1911?].

An administrative report.

Mitchell, Guy Elliott.

768. Potash deposits in America: Cassier's Mag., vol. 41, no. 4, pp. 291–301, 14 figs., April, 1912.

Moffit, Fred H.

769. Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts: U. S. Geol. Survey, Bull. 498, 82 pp., 10 pls., 9 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 349–350, August 19, 1912.

770. The Taral and Bremner River districts: U. S. Geol. Survey, Bull 520, pp. 95–104, 1 pl. (map), 1912.

Describes the stratigraphy and the occurrence and character of gold and copper deposits.

771. The Chitina copper district [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 105–107, 1912.

Moodie, Roy L.

772. The lateral line system in extinct Amphibia: Jour. Morphology, vol. 19, no. 2, pp. 511–540, 17 figs., October, 1908.

773. The skull structure of *Diplocaulus magnicornis* Cope and the amphibian order Diplocaulia: Jour. Morphology, vol. 23, no. 1, pp. 31–39, March 20, 1912.

774. The "stomach stones" of reptiles: Science, new ser., vol. 35, pp. 377–378, March 8, 1912.

775. The Mazon Creek, Illinois, shales and their amphibian fauna: Am. Jour. Sci., 4th ser., vol. 34, pp. 277–285, 4 figs., September, 1912.

776. An American Jurassic frog: Am. Jour. Sci., 4th ser., vol. 34, pp. 286–288, September, 1912.

Moore, Charles J.

777. Recent developments at Leadville, Colorado (discussion): Econ. Geology, vol. 7, no. 6, pp. 590–592, September, 1912.

Moore, Elwood S.

778. Siliceous oolites and other concretionary structures in the vicinity of State College, Pennsylvania: Jour. Geology, vol. 20, no. 3, pp. 259–269, 7 figs., April–May, 1912; Abstract, British Assoc. Adv. Sci., Rept. 81st Meeting, p. 390, 1912.

Describes the occurrence and geologic relations and discusses the origin of siliceous oolites.

779. Hydrothermal alteration of granite and the source of vein-quartz at the St. Anthony mine: Econ. Geology, vol. 7, no. 8, pp. 751–761, 4 figs., December, 1912.

780. The pre-Cambrian beds of northern Ontario: Abstract, British Assoc. Adv. Sci., Rept. 81st Meeting, pp. 390–392, 1912.

Morris, H. C.

781. Prospecting for tungsten: Min. and Sci. Press, vol. 104, p. 885, June 29, 1912.

Munn, M. J.

782. Description of the Claysville quadrangle [Pennsylvania]: U. S. Geol. Survey, Geol. Atlas U. S., Claysville folio (no. 180), 14 pp., 10 figs., 5 pls. (maps and sections), 1912; field edition, 98 pp., 10 figs., 5 folded maps (and sections) in pocket, 1912.

Describes the topography, the stratigraphy of Devonian and Carboniferous formations, the geologic structure, the geologic history, and the mineral resources, chiefly oil, gas, and coal.

783. The Campton oil pool, Kentucky: U. S. Geol. Survey, Bull. 471, pp. 9–17, 2 pls. (map and sections), 1912.

784. Oil and gas development in Knox County, Kentucky: U. S. Geol. Survey, Bull. 471, pp. 18–29, 2 pls. (map and sections), 1912.

785. The Fayette gas field, Alabama: U. S. Geol. Survey, Bull. 471, pp. 30–55, 2 pls. (map and sections), 1912.

786. Explorations for natural gas and oil at Memphis: Tennessee State Geol. Survey, Resources of Tennessee, vol. 2, no. 2, pp. 48–68, 4 figs., 1 pl. (map), February, 1912.

Describes natural flows of gas in the vicinity of Memphis, gives records of borings, and discusses the geologic structure.

787. The Spring Creek oil field, Tennessee: Tennessee State Geol. Survey, Resources of Tennessee, vol. 2, no. 7, pp. 273–285, 1 pl. (map), 1912.

788. Problems of oil and gas accumulations in the Appalachian region: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 17, pp. 428–429, October 19, 1912.

Muttkowski, Richard A.

789. Additional notes on *Trichocnemis aliena* Scudder: Wisconsin Nat. Hist. Soc., Bull., vol. 8, no. 2, pp. 106–109, April, 1910.

Narraway, J. E.

790. List of trilobites found at Ottawa and immediate vicinity: Ottawa Naturalist, vol. 26, no. 8, pp. 98–100, November, 1912.

Nason, Frank L.

791. The bearing of the theories of the origin of magnetic iron ores on their possible extent: Am. Inst. Min. Eng., Bull., no. 67, pp. 695–708, July, 1912; Trans., vol. 43, pp. 291–304, 1913.

Nathorst, A. G.

792. On the value of the fossil floras of the Arctic regions as evidence of geological climates: Smithsonian Inst., Ann. Rept., 1911, pp. 335–344, 1912.

Nattress, Thomas.

793. Geology of the Detroit River area: Ontario, Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 281–287, 1 pl. (map and section), 1912.

Neill, N. P.

Soil survey of parts of Spencer and Warrick, and Scott counties. See Mangum and Neill, no. 716.

Nelson, Wilbur A.

794. Notes on lead in Tennessee: Tennessee State Geol. Survey, Resources of Tennessee, vol. 2, no. 3, pp. 100–117, 7 figs., March, 1912.

Nelson, Wilbur A.—Continued.

795. Lignite and lignitic clay in west Tennessee: Tennessee State Geol. Survey, Resources of Tennessee, vol. 2, no. 4, pp. 157–160, 2 figs., April, 1912.

796. The Monteagle wonder cave [Grundy County, Tennessee]: Tennessee Geol. Survey, Resources of Tennessee, vol. 2, no. 8, pp. 294–306, 7 figs., August, 1912.

Tests on the clays of Henry County. See Kirkpatrick and Nelson, no. 587.

Nevius, J. Nelson.

797. The Castle Dome lead district, Arizona: Min. and Sci. Press, vol. 104, pp. 854–855, 4 figs., June 22, 1912.

Newland, D. H.

798. The mining and quarry industry of New York state; report of operations and production during 1911: New York State Mus., Bull. 161, 114 pp., 1912.

Nickles, John M.

799. Bibliography of North American geology for 1911, with subject index: U. S. Geol. Survey, Bull. 524, 162 pp., 1912.

Norton, W. H., and others.

800. Underground water resources of Iowa: U. S. Geol. Survey, Water-Supply Paper 293, 994 pp., 18 pls., 6 figs. (maps and sections), 1912; Iowa Geol. Survey, vol. 21, pp. 29–1186, 18 pls. (maps and sections), 7 figs. (maps), 1912.

Includes a general account of the geologic formations.

Norwood, Charles J.

801. Report on the progress of the survey for the years 1910 and 1911: Kentucky Geol. Survey, 38 pp., 1 pl. (map), 1912.

An administrative report summarizing the work of the survey.

Ohern, D. W.

802. Director's biennial report to the governor of Oklahoma, 1912; Mineral production of Oklahoma from 1901 to 1911: Oklahoma Geol. Survey, Bull. no. 15, 47 pp., December, 1912.

Ohern, D. W., and **Garrett**, Robert E.

803. The Ponca City oil and gas field: Oklahoma Geol. Survey, Bull. no. 16, 30 pp., 2 pls., 1 fig. (maps), December, 1912.

Describe the stratigraphy, structure, and economic developments.

Olsson, Axel.

804. Description of a new genus and species of Palæechinoidea: Am. Jour. Sci., 4th ser., vol. 33, pp. 442–446, 1 fig., May, 1912.

Describes *Lepidechinoides ithacensis* n. gen. and n. sp. from the Devonian at Ithaca, N. Y., and discusses relationships to allied genera.

805. New and interesting fossils from the Devonian of New York: Bull. Am. Paleont., vol. 5, no. 23, 7 pp., 2 pls., Cornell Univ., Ithaca, N. Y., December 20, 1912.

Describes *Trichotocrinus* n. subgen., *Melocrinus* (*Trichotocrinus*) *harrisi* n. sp., *Melocrinus williamsi* n. sp., and *Melocrinus reticularis* n. sp.

O'Neill, J. J.

806. Belœil and Rougemont mountains, Quebec: Canada Geol. Survey, Summ. Rept., 1911, pp. 293–295, 1912.

Ontario, Bureau of Mines.

Twenty-first annual report of the Bureau of Mines, 1912. See Gibson, no. 361.

Ordóñez, Ezequiel.

807. The recent Guadalajara earthquakes: Seism. Soc. America, Bull., vol. 2, no. 2, pp. 134–137, June, 1912.

Describes earthquake shocks felt at Guadalajara, Mexico, in May, 1912, and discusses their probable cause.

Osborn, Henry Fairfield.

808. Evolution as it appears to the paleontologist: Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 733–739, Cambridge, U. S. A., 1912. [Advance print, 7 pp., 1910.]

809. A means of estimating the age of the mastodon and other Proboscidea: Abstract, Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 782–784, 3 figs., Cambridge, U. S. A., 1912. [Advance print, 3 pp., 3 figs., 1910.]

810. The continuous origin of certain unit characters as observed by a paleontologist. Reprinted from the Harvey lectures, series, 1911–1912, pp. 153–204, 8 figs. Philadelphia, J. B. Lippincott Company [1912?]; Am. Naturalist, vol. 46, pp. 185–206, 249–278, 8 figs., April and May, 1912.

811. Crania of Tyrannosaurus and Allosaurus (Tyrannosaurus contributions no. 3): Am. Mus. Nat. Hist., Mem., new ser., vol. 1, pt. 1, pp. 3–30, 4 pls., 27 figs., June, 1912.

812. Integument of the Iguanodont dinosaur Trachodon: Am. Mus. Nat. Hist., Mem., new ser., vol. 1, pt. 2, pp. 31–54, 6 pls., 13 figs., June, 1912.

813. Craniometry of the Equidæ: Am. Mus. Nat. Hist., Mem., new ser., vol. 1, pt. 3, pp. 55–100, 17 figs., June, 1912.

814. Tetraplasy, the law of the four inseparable factors of evolution: Acad. Nat. Sci. Philadelphia, Jour., 2d ser., vol. 15, pp. 273–309, 1912; Abstract, Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 1, pp. 144–146, 2 figs., 1912.

815. Ten years' progress in vertebrate paleontology; Correlation and paleogeography: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 232–256, June 1, 1912.

Discusses the relations of Tertiary formations in Western States.

816. Phylogeny and ontogeny of the horns of mammals: Science, new ser., vol. 35, pp. 595–596, April 12, 1912.

Paige, Sidney.

817. Description of the Llano and Burnet quadrangles [Texas]: U. S. Geol. Survey, Geol. Atlas U. S., Llano-Burnet folio (no. 183), 16 pp., 7 pls. (maps and illus.), 6 figs., 1912; field edition, 115 pp., 11 pls., 6 figs., 6 maps (in pocket), 1912.

Describes the geographic features, the occurrence, character, and relations of pre-Cambrian, Cambrian, Ordovician, Carboniferous, and Cretaceous formations, the geologic structure, the geologic history, and the mineral resources.

Paige, Sidney—Continued.

818. Gravel as a resistant rock: Jour. Geology, vol. 20, no. 1, pp. 49–52, 1 fig., 1912.

Discusses the physiographic history of a portion of the Silver City quadrangle, New Mexico.

819. Rock-cut surfaces in the desert ranges: Jour. Geology, vol. 20, no. 5, pp. 442–450, 4 figs., July–August, 1912.

820. The origin of turquoise in the Burro Mountains, New Mexico: Econ. Geology, vol. 7, no. 4, pp. 382–392, June, 1912.

821. The geologic and structural relations at Santa Rita (Chino), New Mexico: Econ. Geology, vol. 7, no. 6, pp. 547–559, 1 fig. (map), September, 1912.

822. The Llano-Burnet region, Texas (discussion): Econ. Geology, vol. 7, no. 6, pp. 593–594, September, 1912.

Palache, Charles.

823. Mineralogy and petrography: American Year Book, 1911, pp. 589–590, 1912.

Reviews the progress during the year 1911 and gives a list of the more important publications.

824. The identity of parisite and synchisite: Am. Jour. Sci., 4th ser., vol. 34, p. 490, November, 1912.

Palmer, Howard.

825. Observations on the Sir Sandford Glacier, 1911 [British Columbia]: Geog. Jour., vol. 39, no. 5, pp. 446–453, 4 pls., 1 fig., May, 1912.

Parker, Horatio Newton.

826. Quality of the water supplies of Kansas: U. S. Geol. Survey, Water-Supply Paper 273, 375 pp., 1 pl., 1 fig., 1911.

Includes an account of the general geology and the underground waters.

The quality of some waters of the Coastal Plain of North Carolina. See Clark and others, no. 193.

Parks, Henry M.

827. Road materials in the Willamette Valley: Oregon State Bur. Mines, Bull. no. 1, 63 pp., 15 pls., 1 map, second edition [first edition, January, 1911], January, 1912.

828. The economic geological resources of Oregon: Oregon State Bureau of Mines (Oregon Agric. Coll., Coll. Bull., Extension Series 5, no. 2), 120 pp., illus., 1912.

Parks, William Arthur.

829. The building and ornamental stones of the maritime provinces: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 84–86, 1912.

830. Report on the building and ornamental stones of Canada, vol. 1: Canada, Dept. of Mines, Mines Branch, 376 pp., 77 pls., 21 figs., 1912.

Includes an outline of the geology of Ontario.

Parr, S. W., and **Ernest**, T. R.

831. A study of sand-lime brick: Illinois State Geol. Survey, Bull. no. 18, 83 pp., 6 pls., 4 figs., 1912.

Parsons, Arthur L.

832. Gold fields of Lake of the Woods, Manitou, and Dryden: Ontario, Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 169–204, 35 figs., 1912.

Describes the geology of pre-Cambrian rocks and the gold mines and prospects.

Parsons, Floyd.

833. Mining coal on the Virginian Railroad: Coal Age, vol. 1, pp. 1039–1043, 7 figs., May 18, 1912.

Includes notes on the occurrence and character of coals in southern West Virginia.

Pastor y Giraud, Antonio.

Riesengipskristalle aus Chihuahua, Nord-Mexiko. See Wittich and Pastor y Giraud, no. 1234.

Patton, Horace B., **Hoskin**, Arthur J., and **Butler**, G. Montague.

834. Geology and ore deposits of the Alma district, Park County, Colorado: Colorado State Geol. Survey, Bull. 3, 284 pp., 29 pls., 6 figs., 1912.

Paul, Fred P.

835. Ueber Azurit, Vanadinit, Mimetesit, Calamin: Zeits. Krystal., Bd. 50, H. 6, pp. 600–604, 1912.

Describes azurite from Socorro City, New Mexico, vanadinite from several localities in New Mexico, mimetesite from Chihuahua, Mexico, and calamine from Leadville, Colorado.

Ueber Kieselzinkerz von Santa Eulalia bei Chihuahua, Mexico. See Seebach and Paul, no. 959.

Peach, B. N.

836. The relation between the Cambrian faunas of Scotland and North America: Nature, vol. 90, pp. 49–56, September 12, 1912.

Peale, A. C.

837. On the stratigraphic position and age of the Judith River formation: Jour. Geology, vol. 20, nos. 6, 7, and 8, pp. 530–549, 640–652, 738–757, 1912.

Pearson, J. R., and **Hoff**, L. R.

838. Asbestos and its uses: Canadian Soc. Civil Eng., Trans., vol. 26, pt. 1, pp. 141–155, 3 pls., 1912.

Peck, Frederick B.

839. Preliminary report on the talc and serpentine of Northampton County and the Portland cement materials of the Lehigh district: Pennsylvania Topog. and Geol. Survey, Rept. no. 5, 65 pp., 17 pls. (incl. geol. map), 9 figs., 1911.

Pelton, E. F., and **Irwin**, D. D.

840. The planetable in geologic mapping (discussion): Econ. Geology, vol. 7, no. 8, pp. 778–783, December, 1912.

Penck, Walther.

841. Studien am Kilauea, Hawaii: Gesell. Erdkunde Berlin, Zeitsch., no. 3, pp. 180–203, 1 fig., 1912.

Gives observations on the volcano Kilauea.

Pepperberg, Leon J.

842. The southern extension of the Milk River coal field, Chouteau County, Montana: U. S. Geol. Survey, Bull. 471, pp. 359–383, 1 pl. (map), 1912.

Perisho, E. C., and **Visher**, S. S.

843. A preliminary report upon the geography, geology, and biology of Mellette, Washabaugh, Bennett, and Todd counties, South Dakota: South Dakota State Geol. and Biol. Survey, Bull. no. 5, 152 pp., 50 pls. and maps, 1912.

Gives a general account of the physiographic features, stratigraphy, and mineral resources of south central South Dakota.

Perkins, George H.

844. Report of the State geologist on the mineral industries and geology of Vermont, 1911–1912. Eighth of this series. 269 pp., 83 pls. Montpelier, Vt., 1912.

The various papers have been listed under the individual authors.

845. A general account of the geology of the Green Mountain region: Vermont, State Geologist, Eighth Rept., pp. 17–100, 40 pls., 1912.

846. Mineral resources of Vermont: Vermont, State Geologist, Eighth Rept., pp. 247–269, 2 pls., 1912.

Peterson, O. A.

847. Ten years' progress in vertebrate paleontology; Artiodactyla: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 162–178, June 1, 1912.

848. A group of Stenomylins recently prepared and exhibited in the Carnegie Museum: Carnegie Mus., Annals, vol. 8, no. 2, pp. 366–369, 2 pls., 1 fig., May, 1912.

849. Recently proposed species of the genus Diceratherium: Science, new ser., vol. 36, p. 801, December 6, 1912.

Phalen, W. C.

850. Description of the Kenova quadrangle [Kentucky-West Virginia-Ohio]: U. S. Geol. Survey, Geol. Atlas U. S., Kenova folio (no. 184), 16 pp., 4 pls. (maps and sections), 13 figs., 1912.

Describes topography, the stratigraphy of Carboniferous formations and Pelstocene deposits, igneous rocks, the geologic structure and geologic history, and the economic resources, principally coal and iron.

851. Sulphur, pyrite, and sulphuric acid in 1911: Am. Fertilizer, vol. 36, no. 12, pp. 33–44d, June 15, 1912.

Mineral resources of the United States, 1911: Bauxite and aluminum; chromic iron ore; abrasive materials; potash salts; salt and bromine; sulphur, pyrite, and sulphuric acid; barytes; mineral paints. See no. 1127.

Phillips, Alexander Hamilton.

852. Mineralogy, an introduction to the theoretical and practical study of minerals. 699 pp., 534 figs., New York, The Macmillan Company, 1912.

Phillips, Drury McN.

A reconnaissance report on the geology of the oil and gas fields of Wichita and Clay counties, Texas. See Udden, no. 1121.

Phillips, William Battle.

853. Iron making in Alabama. Third edition, 254 pp., 31 pls. Alabama, Geol. Survey, 1912.

Includes a discussion on the character and occurrence of the iron ores.

854. Sulphur deposits in Culberson (formerly a part of El Paso) County, Texas: Am. Fertilizer, vol. 36, no. 12, pp. 44g–46, 5 figs., June 15, 1912.

Pickard, Byron O.

855. The Oro Grande mine in Grant County, New Mexico: Min. Science, vol. 65, pp. 166–168, 3 figs., February 15, 1912.

Gives notes on the local geology and the character and occurrence of the gold-bearing veins.

856. The Apache mines of the Owl Head district, Arizona: Min. Science, vol. 65, pp. 473–475, May 30, 1912.

Includes notes on the local geology and the character and occurrence of the ore bodies.

Pierce, R. A.

857. The lignite fields of Colorado: Coal Age, vol. 1, pp. 534–538, 9 figs., February 3, 1912.

Piers, Harry.

858. On the occurrence of tin in Nova Scotia: Nova Scotian Inst. Sci., Proc. and Trans., vol. 12, pt. 3, pp. 239–249, March, 1912.

859. Mastodon remains in Nova Scotia: Nova Scotian Inst. Sci., Proc. and Trans., vol. 13, pt. 2, pp. 163–174, August 26, 1912.

Pilsbry, Henry A.

860. Notes on some Pleurotomiidæ of the Cretaceous of New Jersey: Acad. Nat. Sci. Philadelphia, Proc., vol. 63, pt. 3, pp. 534–535, 1 fig., 1912.

Gives notes on *Pleurotomaria crotaloides* (Morton), *P. abbotti* (Gabb), and describes *P. woolmani* n. sp.

Note on a collection of fossils from Wilmington, North Carolina. See Brown and Pilsbry, no. 117.

Pirsson, L. V.

Modifications of the quantitative system of classification of igneous rocks. See Cross and others, no. 240.

Pishel, Max A.

861. Lignite in the Fort Berthold Indian Reservation, North Dakota, north of Missouri River: U. S. Geol. Survey, Bull. 471, pp. 170–186, 2 pls. (map and sections), 1912.

Pittier, Henri F.

862. Kostarika; Beiträge zur Orographie und Hydrographie: Petermanns Mitt., Erzgänzungsheft no. 175, 48 pp., map, 1912.

Describes physiographic features of Costa Rica.

Platen, Paul.

863. Die fossilen Wälder am Amethyst-Mount im Yellowstone-Nationalpark und die mikroskopische Untersuchung ihrer Hölzer: Prometheus, Jahrg. 20, pp. 241–246, 6 figs., January 20, 1909.

Describes fossil wood, with sections illustrating structure, from the Yellowstone National Park.

Pogue, J. E., and **Goldschmidt**, V.

864. On quartz from Alexander County, North Carolina: Am. Jour. Sci., 4th ser., vol. 34, pp. 414–420, 3 figs., November, 1912.

Pohlig, H.

865. Sur une vieille mandibule de "Tetracaulodon ohioticum" Blum., avec défense *in situ:* Soc. Belge Géol., Bull., t. 26, pp. 187–193, 2 figs., 1912.

Describes a mandible of *Tetracaulodon ohioticum* preserving the tusk in place.

Porter, E. A.

866. Placer mining in the Fortymile, Eagle, and Seventymile River districts [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 211–218, 1912.

Prest, Walter Henry.

867. Report on cave examination in Hants County, Nova Scotia: Nova Scotian Inst. Sci., Proc. and Trans., vol. 13, pt. 2, pp. 87–94, 2 figs., August 26, 1912.

Price, George McCready.

868. God's two books, or plain facts about evolution, geology, and the Bible. 183 pp., illus. Washington, D. C., Review and Herald Publishing Association, 1911.

Prindle, L. M., and **Mertie**, J. B., jr.

869. Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River: U. S. Geol. Survey, Bull. 520, pp. 201–210, 1 pl. (map), 1912.

Includes an account of the stratigraphy of the region.

Probert, Frank H.

870. Copper Butte, Ariz., a volcanic throat: Eng. and Min. Jour., vol. 94, pp. 499–500, 2 figs., September 14, 1912.

Prosser, Charles S.

871. The disconformity between the Bedford and Berea formations in central Ohio: Jour. Geology, vol. 20, no. 7, pp. 585–604, 6 figs., 1912.

872. The Devonian and Mississippian formations of northeastern Ohio: Ohio Geol. Survey, Fourth Ser., Bull. 15, 574 pp., 33 pls., 1 fig., December, 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 352–353, August 19, 1912.

Prouty, William Frederick.

873. Map of the Coosa coal field, with sections. 30 × 39 inches. Scale, 1 inch=1.5 miles. Alabama Geol. Survey, 1912.

874. Water-worn coal pebbles in Carboniferous sandstone: Jour. Geology, vol. 20, no. 8, pp. 769–771, 1 fig., 1912.

Prutzman, Paul W.

875. History and geology of California oil fields: Min. and Eng. World, vol. 36, pp. 1191–1192, June 22, 1912.

Purdue, A. H.

876. Compendium of the mineral resources of Arkansas: [Little Rock] Board of Trade Bulletin, 30 pp., 1912.

877. Administrative report of the State geological survey, 1912: Tennessee State Geol. Survey, Bull. 15, 17 pp., 1912.

878. The zinc deposits of northeastern Tennessee: Tennessee State Geol. Survey, Bull. 14, 69 pp., 1 pl. (map), 30 figs., 1912.

879. The zinc deposits of northern Tennessee: Min. Science, vol. 66, pp. 249–251, 2 figs., October 17, 1912.

880. Some neglected principles of physiography: Indiana Acad. Sci., Proc., 1911, pp. 83–87, 1 fig., 1912.

Putnam, George R.

881. Condition of the earth's crust: Science, new ser., vol. 36, pp. 869–871, December 20, 1912.

Quinn, Edward J.

882. Soil survey of Laporte, St. Joseph, and Bartholomew counties: Indiana Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 281–334, 3 pls. (maps), 8 figs., 1912.

Ransome, Frederick Leslie.

883. Economic geology: American Year Book, 1911, pp. 584–585, 1912.

Reviews the progress and principal publications during the year 1911.

884. The planetable in detailed geologic mapping: Econ. Geology, vol. 7, no. 2, pp. 113–119, February–March, 1912.

885. Genesis of the lead-silver ores of Wardner district, Idaho: Min. and Sci. Press, vol. 105, pp. 143–144, August 3, 1912.

Ravn, J. P. J.

886. On Jurassic and Cretaceous fossils from northeast Greenland: Meddelelser om Groenland, Bd. 45, pp. 433–500, 7 pls. (incl. map), 6 figs, 1912.

Raymond, Percy E.

887. The Clymenia fauna in the American Devonian: Intern. Zool. Congr., Seventh, Boston, 1907, Proc., pp. 741–744, Cambridge, U. S. A., 1912.

888. [Report of the] Paleontological division; invertebrate: Canada Geol. Survey, Summ. Rept., 1911, pp. 351–357, 1912.

Includes notes on Ordovician formations in Ottawa valley, Canada.

889. Notes on parallelism among the Asaphidæ: Roy. Soc. Canada, Proc. and Trans., 3d ser., vol. 5, sec. 4, pp. 111–120, 3 pls., 1912.

890. On two new Paleozoic starfish (one of them found near Ottawa), and a new crinoid: Ottawa Naturalist, vol. 26, no. 7, pp. 77–81, 1 pl., 3 figs., October, 1912.

Describes *Palæaster? wilsoni* n. sp. from the Ordovician near Ottawa, Ontario, *Mariacrinus? insuetus* n. sp. from the Devonian Three Forks shale at Logan, Montana, and *Schœnaster, montanus* n. sp. from the Madison limestone at Spring Canon in the Ruby Mountains, near Alder, Montana.

891. On the nature of the so-called "covering plates" in *Protopalæaster narrawayi*: Ottawa Naturalist, vol. 26, no. 9, pp. 105–108, 1 pl., December, 1912.

Read, Thomas T.

892. The Nevada-Douglas mines [Lyon County, Nevada]: Min. and Sci. Press, vol. 105, pp. 206–207, 3 figs., August 17, 1912.

Includes notes on the local geology and the occurrence of the copper ores and gypsum.

Reagan, Albert B.

893. Mineral resources of Jemez-Albuquerque region [New Mexico]: Min. and Eng. World, vol. 36, p. 23, January 6, 1912.

Reed, Margaret.

Mutations of *Spirifer mucronatus*. See Grabau and Reed, no. 391.

Reid, Harry Fielding.

894. Earthquakes and volcanoes: American Year Book, 1911, pp. 590–593, 1912.

Reviews the principal earthquakes and volcanic eruptions during the year 1911.

Reid, Harry Fielding—Continued.

895. List of strong shocks in the United States and dependencies: British Assoc. Adv. Sci., Rept. 81st Meeting, pp. 41–45, 1912.

A list of earthquakes ranging in intensity from I to III between 1663 and 1909.

896. On the choice of a seismograph: Seism. Soc. America, Bull., vol. 2, no. 1, pp. 8–30, 13 figs., 1912.

Describes apparatus for registering earthquake shocks.

897. On the nomenclature of faults: Abstracts, Science, new ser., vol. 35, p. 319, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 1, p. 74, March 14, 1912.

898. The formation of mountain ranges: Abstract, Coal Age, vol. 1, p. 703, March 9, 1912.

899. Note on mountain-producing forces: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 71, March 14, 1912.

Isostasy and mountain ranges: Am. Geog. Soc., Bull., vol. 44, no. 5, pp. 354–360, May, 1912.

Reprinted from Am. Philos. Soc., Proc., vol. 50, pp. 444–451, 1911. See entry no. 919 of U. S. Geol. Survey, Bull. 524, p. 76.

Reinecke, L.

900. Beaverdell map area, Yale district, B. C.: Canada Geol. Survey, Summ. Rept., 1911, pp. 130–132, 1912.

Silver and gold deposits on the west fork of Kettle River: Canadian Min. Inst., Jour., vol. 14, pp. 207–211, 1912. See no. 1038 of the bibliography for 1910, U. S. Geol. Survey, Bull. 495, p. 85.

Requa, Mark L.

901. Present conditions in the California oil fields: Am. Inst. Min. Eng., Trans., vol. 42, pp. 837–846, 1912.

Includes data on the geology of the Midway oil field.

Rice, Claude T.

902. Copper mining at Lake Superior: Eng. and Min. Jour., vol. 94, pp. 119–124, 4 figs., July 20, 1912.

Rice, George S.

Report of the Commission appointed to investigate Turtle Mountain, Frank, Alberta. See Daly and others, no. 257.

Rich, John L.

The properties of ice. See Tarr and Rich, no. 1068.

Richards, R. W., and **Mansfield**, G. R.

903. The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geology, vol. 20, no. 8, pp. 681–709, 5 figs., 1912.

Richardson, C. H.

904. The terranes of Craftsbury, Vermont: Vermont, State Geologist, Eighth Rept., pp. 162–183, 1 pl., 1912.

Describes the distribution, character, and relations of Cambrian, Ordovician, Devonian, and intrusive rocks.

The asbestos deposits of the New England states: Canadian Min. Inst., Jour., vol. 14, pp. 107–117, 1 pl., 1 fig. (discussion, pp. 117–137, 3 figs.), 1912. See no. 937 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 77.

Richardson, C. H., and Collister, M. C.

905. The terranes of Albany, Vermont: Vermont, State Geologist, Eighth Rept., pp. 184–195, 5 pls., 1912.

Describes the general features and the stratigraphy of the area.

Richardson, C. H., and Conway, E. F.

906. The terranes of Irasburg, Vermont: Vermont, State Geologist, Eighth Rept., pp. 146–161, 8 pls., 1912.

Describes the occurrence, character, and relations of Cambrian, Ordovician, and intrusive rocks.

Richardson, Clifford.

907. Trinidad and Bermudez asphalts and their use in highway construction: Pop. Sci. Monthly, vol. 81, no. 1, pp. 19–35, 18 figs., July, 1912.

Richardson, G. B.

908. The Monument Creek group: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 267–276, 1 fig. (map), June 15, 1912.

Describes the Dawson arkose and Castle Rock conglomerate forming the Monument Creek group of Colorado and discusses their relation to the Denver and Arapahoe formations.

909. Monument Creek group and its relations to the Denver and Arapahoe formations: Abstract, Science, new ser., vol. 35, pp. 311–312, February, 1912.

910. Structure of the foothills of the Front Range, central Colorado: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 17, pp. 429–430, October 19, 1912.

Rickard, T. A.

911. The domes of Nova Scotia: Inst. Min. and Metall., Trans., vol. 21, pp. 506–566, 21 pls. (incl. geol. map), 19 figs., 1912; Canadian Min. Jour., vol. 33, pp. 224–230, 273–276, 310–313, 345–348, 16 figs., April and May, 1913; Min. and Sci. Press, vol. 104, pp. 492–494, 4 figs., April 6, 1912.

Discusses the geologic structure of the gold-producing area of Nova Scotia, and the occurrence of the gold ores, and reviews the work of previous writers on the subject.

912. Persistence of ore in depth: Min. and Sci. Press, vol. 105, pp. 232–234, 264–266, August 24 and 31, 1912.

Ries, Heinrich.

913. Building stones and clay products. xv, 415 pp., 59 pls., 20 figs. New York, John Wiley & Sons, 1912.

914. Report on progress of investigation of clay resources: Canada Geol. Survey, Summ. Rept., 1911, pp. 225–229, 1912.

915. Whiteware materials in Ontario and Quebec, kaolin near Huberdeau, Quebec: Canada Geol. Survey, Summ. Rept., 1911, pp. 229–232, 1912.

The clay and shale deposits of the western provinces of Canada: Canadian Min. Inst., Jour., vol. 14, pp. 351–394, 7 pls., 3 figs., 1912. See no. 941 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 77.

Ries, Heinrich, and Keele, Joseph.

916. Preliminary report on the clay and shale deposits of the western provinces: Canada Geol. Survey, Mem. no. 24, 231 pp., 61 pls., 10 figs., 4 maps, 1912.

Riggs, Elmer S.

917. New or little known titanotheres from the lower Uinta formations, with notes on the stratigraphy and distribution of fossils: Field Mus. Nat. Hist., Pub. 159, Geol. ser., vol. 4, no. 2, pp. 17–41, 9 pls., 2 figs., June, 1912.

Ripley, H. Ernestine.

918. Bibliography of the published writings of Henry Fairfield Osborn for the years 1877–1910. 30 pp. Lancaster, Pa., The New Era Printing Company, 1911.

Ris, F.

919. The identity of two Odonata fossils: Wisconsin Nat. Hist. Soc., Bull., vol. 8, no. 2, pp. 102–105, April, 1910.

Discusses the systematic position of two fossil insects described by Scudder from the Tertiary of Colorado.

Robertson, William Fleet.

920. Report of the [British Columbia] Bureau of Mines: British Columbia, Minister of Mines, Ann. Rept., 1911, 313 pp., pls., maps, Victoria, 1912.

Includes notes on the geology and occurrence of various ores in British Columbia.

Rogers, Austin Flint.

921. Introduction to the study of minerals; a combined textbook and pocket manual. 522 pp., 591 figs. New York, McGraw-Hill Book Company, 1912.

922. Baddeleyite from Montana: Am. Jour. Sci., 4th ser., vol. 33, pp. 54–56, January, 1912.

923. Lorandite from the Rambler mine, Wyoming: Am. Jour. Sci., 4th ser., vol. 33, pp. 105–106, 2 figs., February, 1912.

924. The occurrence and origin of gypsum and anhydrite at the Ludwig mine, Lyon County, Nevada: Econ. Geology, vol. 7, no. 2, pp. 185–189, 3 figs., February–March, 1912.

925. Dahllite (podolite) from Tonopah, Nevada; vœlckerite, a new basic calcium phosphate; remarks on the chemical composition of apatite and phosphate rock; with analyses by G. E. Postma: Am. Jour. Sci., 4th ser., vol. 33, pp. 475–482, 2 figs., May, 1912.

926. The paragenesis of minerals: Econ. Geology, vol. 7, no. 7, pp. 638–646, October–November, 1912.

927. Notes on rare minerals from California: School of Mines Quart., vol. 33, no. 4, pp. 373–381, 1 fig., July, 1912.

928. Some notes on the rare minerals of California: Min. and Eng. World, vol. 37, pp. 105–106, July 20, 1912.

929. Orthoclase as a vein mineral: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 72, March 14, 1912.

Rogers, Reese F.

930. The soils and agricultural resources of Robertson County, Tennessee: Tennessee State Geol. Survey, The Resources of Tennessee, vol. 2, no. 12, pp. 442–457, 2 figs., December, 1912.

Romanes, James.

931. Geology of a part of Costa Rica: Geol. Soc. London, Quar. Jour., vol. 69, pt. 1, pp. 103–139, 2 pls., 5 figs., February, 1912.

932. Geological notes on the Peninsula of Nicoya, Costa Rica: Geol. Mag., dec. 5, vol. 9, no. 6, pp. 258–265, 1 fig. (map), June, 1912; (abstract), no. 1, p. 46, January, 1912.

Ruedemann, Rudolf.

933. Note on a specimen of *Plectoceras jason* (Billings): New York State Mus., Bull. 158, pp. 141–142, 1 pl., 1912.

The Eurypterida of New York. See Clarke and Ruedemann, no. 201.

Rueppel, George E.

Seismology in St. Louis University. See Goesse and Rueppel, no. 376.

Salazar S, Leopoldo.

The mining industry of Mexico. No. 1, State of Hidalgo. See González and others, no. 379.

La industria minera de México. Tomo 1, Estados de Hidalgo y México. See Grothe and Salazar S, no. 405.

Sales, Reno H.

934. Review of Butte geological report: Eng. and Min. Jour., vol. 94, pp. 729–731, October 19, 1912.

Savage, T. E.

935. The Channahon and Essex limestones in Illinois: Illinois Acad. Sci., Trans., vol. 4, pp. 97–103, 1 pl., 1912.

Describes the occurrence, character, and fossil contents of these Silurian limestones in northern Illinois and discusses their correlation and the sources of their faunas.

Description of the Murphysboro and Herrin quadrangles [Illinois]. See Shaw and Savage, no. 972.

Schaller, Waldemar T.

936. Mineralogical notes, series 2: U. S. Geol. Survey, Bull. 509, 115 pp., 1 pl., 5 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, p. 349, August 19, 1912.

937. Ferritungstit, ein neues Mineral: Zeitschr. Krystal., Bd. 50, H. 2, pp. 112–113, 1912.

Describes ferritungstite, a new mineral from the Deer Trail mining district, Washington.

938. Crystallized turquoise from Virginia: Am. Jour. Sci., 4th ser., vol. 33, pp. 35–40, 1 fig., January, 1912; Zeitschr. Krystal., Bd. 50, H. 2, pp. 120–125, 1 fig., 1912.

Describes crystallized turquoise from Virginia.

939. New manganese phosphates from the gem tourmaline field of southern California: Washington Acad. Sci., Jour., vol. 2, no. 6, pp. 143–145, March 19, 1912.

940. Crystallized variscite from Utah: U. S. Nat. Mus., Proc., vol. 41, pp. 413–430, 1 pl., 2 figs., 1912; Zeitschr. Krystal., Bd. 50, H. 4–5, pp. 321–342, 2 figs., 1912.

Describes the characters and occurrence, the optical properties, the structure, the crystallography, and the chemical composition.

941. The crystallography of variscite: Washington Acad. Sci., Jour., vol. 2, no. 6, p. 143, March 19, 1912.

942. Die chemische Zusammensetzung des Nephelins: Zeitschr. Krystal., Bd. 50, H. 4–5, pp. 343–346, 1912.

Discusses the chemical composition of nepheline.

Schaller, Waldemar T.—Continued.

943. Barbierit, ein monokliner Natronfeldspat: Zeitschr. Krystal., Bd. 50, H. 4–5, pp. 347–348, 1912.

Proposes the name barbierite for a monoclinic soda feldspar.

944. Beitrag zur Kenntnis der Turmalingruppe: Zeitschr. Krystal., Bd. 51. H. 4, pp. 320–343, 4 figs., 1912.

A study of the tourmaline minerals, including chemical composition.

945. Die Alunit-Beudantitgruppe: Zeitschr. Krystal., Bd. 50, H. 2, pp. 106–111, 1912.

Translation of the paper published in the American Journal of Science, 4th ser., vol. 32, pp. 359–364, November, 1911. See entry no. 988 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 80.

Hinsdalit, ein neues Mineral. See Larsen and Schaller, no 634.

Scharff, Robert Francis.

946. Distribution and origin of life in America. 497 pp., 21 figs. (maps. some paleogeographic). London, Constable & Company, 1911.

Scherer, J.

947. Great earthquakes in the island of Haiti: Seism. Soc. America, Bull., vol. 2, no. 3, pp. 161–180. 1 fig. (map), September, 1912.

948. Notes on remarkable earthquake sounds in Haiti: Seism. Soc. America, Bull., vol. 2, no. 4, pp. 230–232, December, 1912.

Schmid, Hugh S. de.

949. Mica; its occurrence, exploitation, and uses (second edition): Canada, Dept. Mines, Mines Branch, 411 pp., 38 pls., 67 figs., 22 maps, 1912.

950. On the phosphate and feldspar deposits of Ontario and Quebec: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 117–122, 1912.

951. Mica mining in the Province of Quebec: Canadian Min. Jour., vol. 33, pp. 423–426, 6 figs., July 1, 1912.

Schöndorf, Friedrich.

952. Organisation und Aufbau der Armwirbel von Onychaster: Nassauischer Ver. Naturk., Jahrb., Jg. 62, pp. 49–63, 1 pl., Wiesbaden, 1909.

Describes structural features of *Onychaster flexilis* Meek and Worthen.

Schofield, S. J.

953. Reconnaissance in East Kootenay [British Columbia]: Canada Geol. Survey, Summ. Rept., 1911, pp. 158–164, 1 pl. (map), 1912.

954. The origin of the silver-lead deposits of East Kootenay, British Columbia: Econ. Geology, vol. 7, no. 4, pp. 351–363, 6 figs., June, 1912.

Schrader, Frank Charles.

955. A reconnaissance of the Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nevada: U. S. Geol. Survey, Bull. 497, 162 pp., 26 pls., 3 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 18, pp. 439–440, November 4, 1912.

Schroeder, F. C.

Soil survey of Marion County. See Geib and Schroeder, no. 360.

Schuchert, Charles.

956. Jackson on the phylogeny of the Echini: Am. Jour. Sci., 4th ser., vol. 34, pp. 251–263, September, 1912.

Schultz, Alfred R., and **Cross**, Whitman.

957. Potash-bearing rocks of the Leucite Hills, Sweetwater County, Wyoming: U. S. Geol. Survey, Bull. 512, 39 pp., 1 pl., 9 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 6, p. 159, March 19, 1912.

Describes the character, composition, occurrence, and geologic relations of the rocks, and in detail the different exposures.

Schwarz, E. H. L.

958. The Atlantic and Pacific types of coast: Geog. Jour., vol. 40, no. 3, pp. 294–299, September, 1912.

Seebach, M., and **Paul**, F. P.

959. Ueber Kieselzinkerz von Santa Eulalia bei Chihuahua, Mexico, ein Beitrag zur Kenntnis der Krystallformen dieses Mineral: Zeits. Krystal., Bd. 51, H. 2, pp. 149–206, 3 pls., 1912.

Describes the crystallography of siliceous calamine from Santa Eulalia, Chihuahua, Mexico.

Sellards, E. H.

960. Administrative report, 1910–1911: Florida State Geol. Survey, Fourth Ann. Rept., pp. xi–xvi, 1912.

961. The soils and other surface residual materials of Florida, their origin, character, and the formations from which derived; a study in agrogeology: Florida State Geol. Survey, Fourth Ann. Rept., pp. 1–79, 12 pls., 1 map, 3 figs., 1912.

962. Production of phosphate rock in Florida during 1910: Florida State Geol. Survey, Fourth Ann. Rept., pp. 157–168, 1912.

Sellards, E. H., and **Gunter**, Herman.

963. The underground water supply of west central and west Florida: Florida State Geol. Survey, Fourth Ann. Rept., pp. 81–155, 4 pls., 12 figs., 1912.

Sellards, E. H., **Gunter**, H., and **Cox**, N. H.

964. Roads and road materials of Florida: Florida State Geol. Survey, Bull. no. 2, 31 pp., 4 pls., May, 1911.

Shannon, Charles W.

965. Soil survey of Morgan and Owen counties: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 135–280, 4 pls. (maps), 8 figs., 1912.

966. Results of glaciation in Indiana: Indiana Acad. Sci., Proc., 1911, pp. 173–196, 14 figs., 1912.

967. The sand areas of Indiana: Indiana Acad. Sci., Proc., 1911, pp. 197–210, 5 pls., 1912.

Sharwood, W. J.

968. The specific gravity of mixtures (discussion): Econ. Geology, vol. 7, no. 6, pp. 588–590, September, 1912.

Shaw, A. H.

969. The Arkansas semi-anthracite field: Coal Age, vol. 2, no. 15, pp. 486–488, 3 figs., October 12, 1912.

Shaw, E. W.

970. The Carlyle oil field and surrounding territory: Illinois State Geol. Survey, Extract from Bull. 20, pp. 7–37, 7 pls. (maps and sections), 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, pp. 108–109, February 19, 1912.

Shaw, E. W.—Continued.

971. Koenigsberger on geothermic gradients and petroleum: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 15, pp. 393–394, September 19, 1912.

Shaw, E. W., and **Savage, T. E.**

972. Description of the Murphysboro and Herrin quadrangles [Illinois]: U. S. Geol. Survey, Geol. Atlas U. S., Murphysboro-Herrin folio (no. 185), 15 pp., 6 pls. (maps), 13 figs., 1912.

Describes the physiographic features, the occurrence, character, and relations of Carboniferous strata and Quaternary deposits, the geologic structure and history, and the mineral resources, chiefly coal and clay.

Sheldon, G. L.

973. Railroad Valley potash fields [Nye Co., Nev.]: Min. and Sci. Press, vol. 105, pp. 502–503, October 19, 1912.

Sheldon, Pearl.

974. Some observations and experiments on joint planes: Jour. Geology, vol. 20, nos. 1 and 2, pp. 53–79, 164–190, 13 figs., 1912.

Describes experiments on the production of joint planes and discusses the results and the application to Devonian rocks in the Ithaca region, New York.

Shimek, B.

975. Memoir of Samuel Calvin: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 4–12, 1 pl. (port.), March 14, 1912.

Includes a list of his writings.

976. Pleistocene of Sioux Falls, South Dakota, and vicinity: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 125–154, 4 pls., 1 fig., March 27, 1912.

977. Mingling of Pleistocene formations: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 709–712, 1 pl., 1 fig., December 4, 1912. Abstract, Science, new ser., vol. 35, p. 317, February, 1912.

Explains how the mingling of Pleistocene formations in sections exposed at Des Moines, Iowa, and at Sioux Falls, S. Dak., was produced by glacial action.

978. Loess a lithological term: Abstract, Science, new ser., vol. 35, p. 317, February 23, 1912. Abstract (with discussion by F. V. Emerson, G. Frederick Wright, and Frank Leverett): Geol. Soc. America, Bull., vol. 23, no. 4, pp. 738–739, December 17, 1912.

Siebenthal, C. E.

979. The copper, lead, and zinc industries of the South: Manufacturers Record, vol. 61, no. 7, pt. 2, pp. 61–63, February 22, 1912.

Mineral resources of the United States, 1911: Lead; zinc; cadmium. See no. 1127.

Simmons, Jesse.

980. The Cambria coal field in Wyoming: Coal Age, vol. 1, pp. 766–768, 2 figs., March 23, 1912.

981. The Sheridan, Wyo., coal field: Coal Age, vol. 1, pp. 866–868, 4 figs., April 13, 1912.

Simon, A. L.

Gels, gelatinous quartz, and gold-ore deposition. See Hatschek and Simon, no. 434.

Simpson, H. E.

Underground water resources of Iowa. See Norton and others, no. 800.

Sinclair, William J.

982. Ten years' progress in vertebrate paleontology; Contributions to geologic theory and method by American workers in vertebrate paleontology: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 262–266, June 1, 1912.

983. Some glacial deposits east of Cody, Wyoming, and their relation to the Pleistocene erosional history of the Rocky Mountain region: Abstract, Science, new ser., vol. 35, pp. 314–315, February, 1912.

984. Some glacial deposits east of Cody, Wyoming, and their relation to the Pleistocene erosional history of the Rocky Mountain region (abstract, with discussion by W. W. Atwood): Geol. Soc. America, Bull., vol. 23, no. 4, p. 731, December 17, 1912.

Sinclair, William J., and **Granger**, Walter.

985. Notes on the Tertiary deposits of the Bighorn basin: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 57–67, 2 pls., 1 fig., 1 map, 1912.

Singewald, Joseph T., jr.

986. Origin of iron ores: Econ. Geology, vol. 7, no. 2, pp. 191–195, February–March, 1912.

987. Some genetic relations of tin deposits: Econ. Geology, vol. 7, no. 3, pp. 263–279, April–May, 1912.

988. The iron ore deposits of the Cebolla district, Gunnison County, Colorado: Econ. Geology, vol. 7, no. 6, pp. 560–573, 3 figs. (incl. map), September, 1912.

Skertchly, Sydney A. R.

989. The Mexican oil fields: Min. Mag., vol. 7, no. 3, pp. 199–203, 2 figs., September, 1912.

Smith, Burnett.

990. Observations on the structure of some coral beds in the Hamilton shale [of New York]: Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 2, pp. 446–454, 2 pls., 1 fig., August, 1912.

Smith, Dwight T.

991. Vein systems of the Comstock: Eng. and Min. Jour., vol. 94, pp. 895–896, November 9, 1912.

Smith, George Otis.

992. Thirty-third annual report of the Director of the United States Geological Survey to the Secretary of the Interior for the fiscal year ended June 30, 1912. 175 pp., 2 maps. Washington, 1912.

An administrative report summarizing the activities of the Survey during the fiscal year 1911–1912.

993. The policy of the Geological Survey: Science, new ser., vol. 36, pp. 401–403, September 27, 1912.

Smith, James Perrin.

994. On the distribution of Lower Triassic faunas: Jour. Geology, vol. 20, no. 1, pp. 13–20, 1912.

995. The occurrence of coral reefs in the Triassic of North America: Am. Jour. Sci., 4th ser., vol. 33, pp. 92–96, February, 1912.

996. Geologic range of Miocene invertebrate fossils of California: California Acad. Sci., Proc., vol. 3, pp. 161–182, April 5, 1912.

Smith, Philip S.

997. Glaciation in northwestern Alaska: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 563–570, 3 pls., 1 fig. (map), November 12, 1912; Abstract, Science, new ser., vol. 35, p. 314, February 23, 1912.

998. The Alatna-Noatak region [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 315–338, 1 pl. (map), 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 18, pp. 438–439, November 4, 1912.

Describes the stratigraphy of the region and the economic prospects.

999. Notes on mining in Seward Peninsula [Alaska]: U. S. Geol. Survey, Bull. 520, pp. 339–344, 1912.

1000. Fall of volcanic ash on Seward Peninsula, Alaska: Washington Acad. Sci., Jour., vol. 2, no. 16, pp. 406–407, October 4, 1912.

1001. Geology of the Koyukuk-Kobuk region, Alaska: Abstract, Min. and Eng. World, vol. 36, p. 819, April 23, 1912.

Smith, R. A.

Michigan coal; Michigan gypsum; oil and gas in Michigan. See Allen and others, no. 13.

Smith, W. S. Tangier.

1002. The teaching of economic geology (discussion): Econ. Geology, vol. 7, no. 3, pp. 297–298, April–May, 1912.

1003. Origin of the sandstone at the state prison near Carson City, Nevada: Abstract, Geol. Soc. America, Bull., vol. 23, no. 1, p. 73, March 14, 1912.

Smyth, C. H., jr.

1004. On the genesis of the pyrite deposits of St. Lawrence County: New York State Mus., Bull. 158, pp. 143–183, 12 pls., 5 figs., 1912.

Snider, L. C.

1005. Preliminary report on the lead and zinc of Oklahoma: Oklahoma Geol. Survey, Bull. no. 9, 97 pp., 16 figs., Norman, July, 1912.

Soper, Edgar K.

1006. The geology and mining of clay: Eng. and Min. Jour., vol. 93, pp. 263–267, February 3, 1912.

1007. Modern theories of ore deposition: Mexican Min. Jour., vol. 14, nos. 2 and 3, pp. 22–26, 38–43, February and March, 1912; Mines and Methods, vol. 3, no. 8, pp. 449–457, April, 1912.

Spencer, Arthur C.

Occurrence, origin, and character of the surficial iron ores of Camaguey and Oriente Provinces, Cuba: Am. Inst. Min. Eng., Trans., vol. 42, pp. 103–109, 1912. See no. 1044 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Spencer, Joseph William Winthrop.

1008. Postglacial erosion and oxidation (discussion): Geol. Soc. America, Bull., vol. 23, no. 2, p. 296, June 1, 1912.

1009. Hanging valleys and their preglacial equivalents in New York: Geol. Soc. America, Bull., vol. 23, no. 4, pp. 477–486, 3 figs., October 12, 1912; Abstract, Science, new ser., vol. 35, p. 316, February 23, 1912.

Discusses the origin of the Lakes Cayuga and Seneca and presents evidence to show that the hanging valleys in New York are not due to glacial deepening of lake basins.

Spencer, Joseph William Winthrop—Continued.

1010. Covey Hill revisited (with discussion by J. B. Woodworth, H. L. Fairchild, and the author, on p. 722): Geol. Soc. America, Bull., vol 23, no. 4, pp. 471–476, 1 fig., October 12, 1912; Abstract, Science, new ser., vol. 35, pp. 310–311, February 23, 1912.

Discusses the beaches on Covey Hill, in Quebec, near the international boundary.

Suboceanic physical features off the coast of North America and the West Indian Islands. See Hull, no. 522.

Sperr, F. W.

1011. Failures of the rule of following the hanging in the development of Lake Superior copper mines (with discussion): Lake Superior Min. Inst., Proc., vol. 17, pp. 238–246, 3 figs., 1912.

Includes notes on faulting and the occurrence of the copper ores.

Sperry, Edwin A.

1012. Investigation of Feather River black sands [California]: Min. and Sci. Press, vol. 105, pp. 624–626, 2 figs., November 16, 1912.

Springer, J. F.

1013. Asbestos, its production and industrial applications: Cassier's Mag., vol. 42, no. 4, pp. 298–309, 12 figs., October, 1912.

1014. The production and uses of mica: Cassier's Mag., vol. 42, no. 5, pp. 444–448, November, 1912.

Spurr, J. E.

1015. Theory of ore deposition: Econ. Geology, vol. 7, no. 5, pp. 485–492, August, 1912.

Spurr, J. E., **Garrey**, G. H., and **Fenner**, Clarence N.

1016. Study of a contact metamorphic ore deposit; the Dolores mine, at Matehuala, S. L. P., Mexico: Econ. Geology, vol. 7, no. 5, pp. 444–484, 3 figs., August, 1912.

Staff, Hans von.

1017. Monographie der Fusulinen, Teil III; Die Fusulinen (Schellwienien) Nordamerikas: Palaeontographica, Bd. 59, L. 3–4, pp. 157–191, 6 pls., 17 figs., April, 1912.

Stansfield, John.

1018. Certain mica, graphite, and apatite deposits of the Ottawa Valley, and an occurrence of *Eozoon canadense*: Canada Geol. Survey, Summ. Rept., 1911, pp. 280–285, 1912.

Statz, B. A.

1019. The new placer mining district, New Mexico: Min. Science, vol. 66, p. 167, September 12, 1912.

Gives notes on placers in Santa Fe County, N. Mex.

1020. Hell Canyon mining district, New Mexico: Min. Science, vol. 66, p. 201, September 26, 1912.

Gives notes on the character and occurrence of the copper ores.

1021. Geology of the Cochita mining district, New Mexico: Min. Science, vol. 66, pp. 276–277, 1 fig., October 31, 1912.

1022. Geology of the Magdalena district, New Mexico: Min. Science, vol. 66, pp. 406–407, 1 fig., December 26, 1912.

Stauffer, Clinton R.

1023. The Devonian of southwestern Ontario: Canada Geol. Survey, Summ. Rept., 1911, pp. 269–272, 1912.

1024. Oriskany sandstone of Ontario: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 371–376, July 29, 1912.

Discusses the relations of the Oriskany and Onondaga formations in Ontario.

Stauffer, Clinton R., **Hubbard**, George D., and **Bownocker**, J. A.

1025. Geology of the Columbus quadrangle: Ohio Geol. Survey, 4th ser., Bull. 14, 133 pp., 28 pls., 16 figs., 3 maps (in pocket), 1911.

Stebinger, Eugene.

1026. The Sidney lignite field, Dawson County, Montana: U. S. Geol. Survey, Bull. 471, pp. 284–318, 4 pls. (map and sections), 1 fig., 1912.

Steel, A. A.

1027. Coal mining in Arkansas, Part I: Arkansas, Geol. Survey, 632 pp., 14 pls., 90 figs., 1910 [published 1912?].

Stefanini, G.

1028. Sugli echini terziari dell'America del Nord: Soc. Geol. Italiana, Boll., vol. 30, pp. 677–714, 1 pl., 1912.

Gives a revision of American Tertiary echinids, including descriptions of several species, one new, *Clypeaster dourillei*.

Stephenson, L. W.

The Coastal Plain of North Carolina; the Cretaceous formations; Lafayette formations; Quaternary. See Clark and others, no. 193.

Stephenson, L. W., and **Johnson**, B. L.

Water resources of the Coastal Plain of North Carolina. See Clark and others, no. 193.

Sterrett, Douglas B.

1029. Gems and precious stones: U. S. Geol. Survey, Min. Res. U. S., 1911, pt. 2, pp. 1037–1078, 1912.

1030. An occurrence of emeralds in North Carolina: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, pp. 360–361, August 19, 1912.

Mineral resources of the United States, 1911: Gems and precious stones; mica; monazite and zircon. See no. 1127.

Stevens, Blamey.

1031. Replacement ore bodies (discussion): Econ. Geology, vol. 7, no. 2, pp. 195–201, 1 fig., February–March, 1912.

1032. The laws of igneous emanation pressure: Am. Inst. Min. Eng., Bull., no. 64, pp. 411–427, 2 pls., 11 figs., April, 1912; Trans., vol. 43, pp. 167–183, 2 pls., 11 figs., 1913.

1033. Physical data of igneous emanation: Am. Inst. Min. Eng., Bull., no. 64, pp. 429–438, 2 figs., April, 1912; Trans., vol. 43, pp. 184–193, 2 figs., 1913.

Stevens, Neil E.

1034. Notes on the structure and glaciation of Overlook Mountain [New York]: New York Acad. Sci., Annals, vol. 22, pp. 259–266, 4 figs., October 15, 1912.

1035. A palm from the upper Cretaceous of New Jersey: Am. Jour. Sci., 4th ser., vol. 34, pp. 421–436, 24 figs., November, 1912.

Stevenson, John J.

1036. The formation of coal beds, III: Am. Philos. Soc., Proc., vol. 51, no. 207, pp. 423–553, 1912.

Stewart, C. A.

1037. The geology and ore deposits of the Silverbell mining district, Arizona: Am. Inst. Min. Eng., Bull., no. 65, pp. 455–505, 18 figs., May, 1912; Trans., vol. 43, pp. 240–290, 18 figs., 1913.

1038. Geology in the examination of prospects: Min. and Sci. Press, vol. 104, pp. 622–623, May 4, 1912.

1039. Geology of ore deposits of Silverbell district, Arizona: Min. and Eng. World, vol. 36, pp. 1104–1107, 1147–1150, 7 figs., May 25 and June 1, 1912.

Note on the effect of calcite gangue. See Welsh and Stewart, no. 1181.

Stewart, R. B.

1040. West Shiningtree gold district: Ontario, Bur. Mines, Twenty-first Ann. Rept., vol. 21, pt. 1, pp. 271–277, 2 pls. (maps), 1912.

Describes the geology of the district and the occurrence of gold.

Stines, Norman C.

1041. The camp of High Grade in northern California; historical facts and a description of the geology of the Hoag district in Modoc County: Min. Science, vol. 65, pp. 27–29, 1 fig., January 11, 1912.

1042. Geology of High Grade district [California]: Mining Investor, vol. 66, no. 12, pp. 192–193, May 6, 1912.

Stoek, H. H.

1043. Geology, mining, and preparation of anthracite: Western Soc. Eng., Jour., vol. 17, no. 8, pp. 705–724, 12 figs., October, 1912.

Stoltz, Guy C.

1044. The Cheever mines, Port Henry, N. Y.: Eng. and Min. Jour., vol. 92, pp. 809–812, 5 figs., October 21, 1911.

Includes notes on the geology of the magnetite ore bodies.

Stone, Ralph W.

1045. Coal near the Black Hills, Wyoming-South Dakota: U. S. Geol. Survey, Bull. 499, 66 pp., 7 pls., 8 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 15, pp. 389–390, September 19, 1912.

1046. Coal on Dan River, North Carolina: U. S. Geol. Survey, Bull. 471, pp. 137–169, 1 pl. (map), 4 figs., 1912.

1047. Classification of metalliferous mineral lands: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, p. 361, August 19, 1912.

Stone, S. R.

1048. Phosphate deposits and mining methods in the United States: Min. and Eng. World, vol. 36, pp. 511–512, March 2, 1912.

Stopes, Marie C.

1049. Paleobotany versus stratigraphy in New Brunswick: Geol. Mag., dec. 5, vol. 9, no. 10, pp. 467–468, October, 1912.

Outline of a memoir discussing the age of certain beds.

Storm, L. W.

1050. The Valdez gold-mining district, Alaska: Min. and Eng. World, vol. 36, pp. 653–655, 3 figs., March 23, 1912.

Storms, William H.

1051. Mineral deposits of the Sierra Nevada, California: Min. and Eng. World, vol. 36, pp. 121–122, January 20, 1912.

1052. The High Grade mining district [Modoc County, California]: Min. and Sci. Press, vol. 105, pp. 273–275, 3 figs., August 31, 1912; Mines and Methods, vol. 4, no. 1, pp. 22–24, 2 figs., September, 1912.

Includes notes on the local geology and the occurrence of the gold ores.

1053. Possibilities of the Mother Lode in depth: Min. and Sci. Press, vol. 105, pp. 459–462, 3 figs., October 12, 1912.

Includes notes on the local geology and the occurrence and character of the ore bodies.

1054. The Helester mines of California: Eng. and Min. Jour., vol. 92, p. 858, October 28, 1911.

Includes notes on the geology of the gold-ore deposits.

1055. The California State Mining Bureau: Min. and Sci. Press, vol. 105, pp. 821–823, December 28, 1912.

Stose, George W.

1056. Description of the Apishapa quadrangle [Colorado]: U. S. Geol. Survey, Geol. Atlas U. S., Apishapa folio (no. 186), 12 pp., 4 pls. (maps and illus.), 20 figs., 1912.

Describes the topography and drainage, the stratigraphy of Cretaceous, Tertiary, and Quaternary formations, the geologic structure, the igneous rocks, the geologic history, and the mineral resources.

1057. The salt and gypsum deposits of southwestern Virginia: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, p. 361, August 19, 1912.

A Mississippian delta. See Branson, no. 103.

Stose, George W., and **Swartz,** Charles K.

1058. Description of the Pawpaw and Hancock quadrangles [Maryland-West Virginia-Pennsylvania]: U. S. Geol. Survey, Geol. Atlas U. S., Pawpaw-Hancock folio (no. 179), 24 pp., 11 figs., 9 pls. (maps, sections, and illustrations), 1912; field edition, 176 pp., 11 figs., 20 pls., 6 folded maps (in pocket), 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 16, p. 410, October 4, 1912.

Describes the topography, the character, occurrence, and relations of Cambrian, Ordovician, Silurian, Devonian, and Carboniferous formations, and of Tertiary and Quaternary deposits, the geologic structure, the geologic history, and the mineral resources.

Stutzer, O.

1059. The origin of sulphur deposits (translated by W. C. Phalen): Econ. Geology, vol. 7, no. 8, pp. 732–743, 4 figs., December, 1912.

1060. Amerikanisches Kalisalz: Kali, Jg. 6, H. 12, pp. 294–295, June 15; H. 17, pp. 432–433, September 1, 1912; Jg. 7, H. 3, pp. 49–50, February 1, 1913.

Discusses the exploration for potash salts in western United States.

Sullivan, George M.

Report on the coal field adjacent to Pineville Gap in Bell and Knox counties. See Crandall and Sullivan, no. 232.

Surr, Gordon.

1061. The search for potash in western United States: Min. and Eng. World, vol. 37, pp. 103–104, July 20, 1912.

Swartz, Charles K.

Description of the Pawpaw and Hancock quadrangles. See Stose and Swartz, no. 1058.

Talmage, James E.

1062. The Deseret Museum: Deseret Museum Bull., new ser., no. 1, 32 pp. 22 figs., August 16, 1911.

Includes an account (pp. 26–28) with figures of mammoth selenite crystals from southern Utah.

Tarr, Ralph S.

1063. The glaciers and glaciation of Alaska: Science, new ser., vol. 35, pp. 241–258, February 16, 1912.

1064. The larger physiographic features of New York: Jour. Geog., vol. 10, no. 7, pp. 209–213, March, 1912.

1065. The theory of advance of glaciers in response to earthquake shaking: Zeitschr. Gletscherkunde, Bd. 5, H. 1, pp. 1–35, 9 figs, September, 1910.

Includes data on the glaciers of Yakutat Bay region, Alaska.

Tarr, Ralph S., and **Martin**, Lawrence.

1066. The earthquakes at Yakutat Bay, Alaska, in September, 1899; with a preface by G. K. Gilbert: U. S. Geol. Survey, Prof. Paper no. 69, 135 pp., 33 pls., 5 figs., 1912; Abstract, Washington Acad. Sci., Jour., vol. 2, no. 17, pp. 421–422, October 19, 1912.

1067. Glacial deposits of the continental type in Alaska: Abstract, Science, new ser., vol. 35, p. 313, February 23, 1912; Abstract (with discussion by C. A. Davis and W. M. Davis), Geol. Soc. America, Bull., vol. 23, no. 4, pp. 729–730, 1912.

Tarr, Ralph S. and **Rich**, John L.

1068. The properties of ice; experimental studies: Zeitschr. Gletscherkunde, Bd. 6, H. 4, pp. 225–249, 15 figs., April, 1912.

Tarr, W. A.

1069. The lack of association of the irregularities of the lines of magnetic declination and the petroleum fields: Econ. Geology, vol. 7, no. 7, pp. 647–661, 3 figs., October–November, 1912.

Taylor, Charles F., and **Booth**, William M.

1070. The Ontario iron mine, New York: Eng. and Min. Jour., vol. 94, pp. 893–895, 6 figs., November 12, 1912.

Taylor, Frank B.

1071. Pleistocene deposits of southwestern Ontario: Canada Geol. Survey, Summ. Rept., 1911, pp. 262–268, 1912.

1072. Recent studies of the moraines of Ontario and western New York: Abstract, Science, new ser., vol. 35, p. 315, February 23, 1912; (title only; discussion by H. L. Fairchild): Geol. Soc. America, Bull., vol. 23, no. 4, pp. 736–737, December 17, 1912.

Taylor, H. B.

1073. A study of ores from Austin, Nev.: School of Mines Quart., vol. 34, no. 1, pp. 32–39, 6 figs., November, 1912.

Describes the character, mineralogy, and occurrence of the silver ores.

Tharp, W. E., and **Mann**, Charles J.

1074. Soil survey of Greene County: Indiana, Dept. Geology and Nat. Res., 36th Ann. Rept., pp. 408–446, 1 pl. (map), 1 fig., 1912.

Thiessen, Reinhardt.

1075. On certain constituents and the genesis of coals: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 9, pp. 232–233, May 4, 1912.

Thomas, A. O.

1076. Additional evidence of unconformity between the Cedar Valley and Lime Creek stages of the Devonian of Iowa: Abstract, Science, new ser., vol. 36, pp. 569–570, October 25, 1912.

1077. Some notes on the Aftonian mammals: Abstract, Science, new ser., vol. 36, p. 570, October 25, 1912.

Underground water resources of Iowa. See Norton and others, no. 800.

Thomas, Kirby.

1078. Vanadium in southwestern Colorado: Min. and Sci. Press, vol. 104, p. 168, January 27, 1912.

1079. The Cuyuna iron range: Min. and Sci. Press, vol. 105, pp. 52–53, July 13, 1912.

1080. The Sudbury nickel district, Ontario, Canada: Min. and Sci. Press, vol. 105, p. 433, 1 fig., October 5, 1912.

Includes notes on the local geology and the occurrence of the nickel ores.

Thompson, Arthur.

1081. The Katalla, Alaska, oil field: Min. and Sci. Press, vol. 105, pp. 169–170, 3 figs., August 10, 1912.

Thompson, W. P.

1082. The structure of the stomata of certain Cretaceous conifers: Bot. Gazette, vol. 54, no. 1, pp. 63–67, 2 pls., July, 1912.

Thomson, Elihu.

1083. The fall of a meteorite: Am. Acad. Arts and Sci., Proc., vol. 47, no. 19, pp. 721–733, March, 1912.

Presents and discusses evidence for the origin of Meteor Crater (Coon Butte), Ariz., by meteoric impact.

Thomson, Robert Boyd, and **Allin**, Arthur Everett.

1084. Do the Abietineæ extend to the Carboniferous?: Bot. Gazette, vol. 53, no. 4, pp. 339–344, 1 pl., 2 figs., April, 1912: Abstract, Science, new ser., vol. 35, p. 159, January 26, 1912.

Thwaites, Turville Fredrik.

1085. Sandstones of the Wisconsin coast of Lake Superior: Wisconsin Geol. and Nat. Hist. Survey, Bull. no. 25 (Sci. Ser. no. 8), 117 pp., 23 pls., 10 figs., 1 map (in pocket), 1912.

Describes the stratigraphy, structure, and relations of the sandstones along the shore of Lake Superior in Wisconsin.

Map of Wisconsin showing geology and roads, 1911. See Hotchkiss and Thwaites, no. 501.

Tibby, B. F.

Field classification of igneous rocks. See Johnson and Tibby, no. 553.

Tilton, John L.

1086. The first reported petrified American Lepidostrobus is from Warren County, Iowa: Iowa Acad. Sci., Proc., vol. 19, pp. 163–165, 1912.

Todd, Charles A.

1087. A problematical geological phenomenon in Colorado: Abstract, Science, new ser., vol. 35, p. 715, May 3, 1912.

Todd, J. E.

1088. Pre-Wisconsin channels in southeastern South Dakota and northeastern Nebraska: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 463–470, 3 pls., September 26, 1912.

Toll, R. H.

1089. Mineral Hill, Nevada: Min. and Sci. Press, vol. 104, pp. 888–889, 1 fig., June 29, 1912.

Includes notes on the local geology.

Tolman, C. F.

1090. Magmatic origin of ore-forming solutions: Min. and Sci. Press, vol. 104, pp. 401–404, March 16, 1912.

1091. The teaching of economic geology (discussion): Econ. Geology, vol. 7, no. 4, pp. 393–399, June, 1912.

1092. Persistence of ore in depth: Min. and Sci. Press, vol. 105, pp. 311–312, September 7, 1912.

1093. An Arizona earthquake [August 18, 1912]: Seism. Soc. America, Bull., vol. 2, no. 3, pp. 209–210, September, 1912.

Tovote, W. L.

1094. Magmatic origin of ore-forming solutions: Min. and Sci. Press, vol. 104, pp. 601–602, April 27, 1912.

1095. Types of porphyry copper deposits: Min. and Sci. Press, vol. 104, 1 fig., May 18, 1912.

Tristán, J. Fidel.

1096. Continuación de la lista de temblores.—Cleto González Viquez, Temblores, terremotos, inundaciones, y erupciones volcánicas en Costa Rica, 1608–1910: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 16–17, 1912.

A list of earthquakes during November and December, 1910, in Costa Rica.

1097. Apuntes sobre el temblor del 25 de Agosto: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 43–45, 1912.

Gives data on the earthquake of August 25, 1911, in Costa Rica.

1098. Notas sobre el terremoto de Guatuso 10 de octubre de 1911: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 47–51, 1 fig., 1912.

Gives data on the earthquake of October 11, 1911, of Guatuso, Costa Rica.

1099. Actividad sísmica en Costa Rica, 1910–1911: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 53–59, 1912.

Discusses earthquakes in Costa Rica during 1910–1911.

1100. El temblor del 21 de junio de 1900: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 61–62, 1912.

Gives notes on the earthquake of June 21, 1900, in Costa Rica.

1101. Apuntes acerca del antiguo volcán "Reventado": Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 63–65, 1912.

Gives observations on phenomena observed in the crater of the volcano "Reventado."

Tristán, J. Fidel, and **Biolley**, Pablo.

1102. Registro de temblores, 1911: Costa Rica, Centro de Estudios Sismológicos, Anales, año 1911, pp. 18–32, 1912.

A list of earthquakes in Costa Rica during 1911 as registered at seismological stations.

Tristán, J. Fidel, **Biolley**, Pablo, and **Cots**, Cesar.

1103. The Sarchi earthquake, Costa Rica: Seism. Soc. America, Bull., vol. 2, no. 3, pp. 201–208, September, 1912.

Trowbridge, Arthur C.

1104. Geology and geography of the Wheaton quadrangle: Illinois State Geol. Survey, Bull. no. 19, 79 pp., 12 pls., 17 figs., 1912.

True, Frederick W.

1105. Description of a new fossil porpoise of the genus Delphinodon from the Miocene formation of Maryland: Acad. Nat. Sci. Philadelphia, Jour., 2d ser., vol. 15, pp. 163–194, 10 pls., 1912; Abstract, Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 1, pp. 135–136, 1912.

1106. The genera of fossil whalebone whales allied to Balaenoptera: Smithsonian Misc. Coll., vol. 59, no. 6, pp. 1–8, April 3, 1912.

1107. Ten years' progress in vertebrate paleontology; Marine mammals: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 197–200, June 1, 1912.

1108. On the correlation of North American and European genera of fossil cetaceans: Abstract, Intern. Zool. Congress, Seventh, Boston, 1907, Proc., pp. 779–781, Cambridge, U. S. A., 1912.

Trueman, J. D.

1109. The value of certain criteria for the determination of the origin of foliated crystalline rocks: Jour. Geology, vol. 20, nos. 3 and 4, pp. 228–258, 300–315, 12 figs., 1912.

Turner, H. W.

1110. Replacement of siliceous rock by pyrite (discussion): Econ. Geology, vol. 7, no. 7, p. 709, October–November, 1912.

1111. Gossan outcrops of cupriferous pyrite: Min. Mag., vol. 7, no. 5, pp. 357–361, 3 figs., November, 1912.

Turner, James W.

1112. Wonders of the great Mammoth Cave of Kentucky, containing thorough and accurate historical and descriptive sketches of this marvelous underground world, with a chapter on the geology of cave formation. 116 pp., 5 pls. Carrier Mills, Ill., Turner Publishing Company, 1912.

Tuttle, Edgar G.

1113. The Magdalena mining district, New Mexico: Mines and Minerals, vol. 33, pp. 275–277, 3 figs., December, 1912.

Twenhofel, William H.

1114. Physiography of Newfoundland: Am. Jour. Sci., 4th ser., vol. 33, pp. 1–24, January, 1912.

Tyrrell, J. B.

1115. Vein formation in Cobalt: Canadian Min. Jour., vol. 33, pp. 171–172, March 1, 1912.

1116. Law of the pay streak in placer deposits: Min. and Sci. Press, vol. 104, pp. 760–762, 9 figs., June 1, 1912.

Udden, Johan A.

1117. Geology and mineral resources of the Peoria quadrangle, Illinois: U. S. Geol. Survey, Bull. 506, 103 pp., 9 pls. (incl. maps), 16 figs., 1912; Abstract (by David White), Washington Acad. Sci., Jour., vol. 2, no. 18, p. 440, November 4, 1912.

1118. The eastward extension of the Sweetland Creek shale in Illinois: Illinois Acad. Sci., Trans., vol. 4, pp. 103–107, 1912.

Describes the occurrence in outcrop of the shale in Iowa and its eastward extension in Illinois as shown by borings.

1119. Oil and gas fields of Wichita and Clay counties, Texas: Min. and Eng. World, vol. 36, p. 767, April 6, 1912.

1120. Potash in the Permian rocks of Texas: The American Fertilizer, vol. 37, no. 12, pp. 40–41, December 14, 1912.

Gives notes on the strata penetrated in a boring at Spur, Dickens Co., Tex., and the potash content of samples of water taken from the well.

Udden, Johan, assisted by Phillips, Drury McN.

1121. A reconnaissance report on the geology of the oil and gas fields of Wichita and Clay counties, Texas: Texas, Univ., Bull. no. 246 (Scient. ser. no. 23), 308 pp., 26 pls. (incl. maps), 8 figs., 1912.

Uglow, W. L.

The Alexo mine; a new nickel occurrence in northern Ontario: Canadian Min. Inst., Jour., vol. 14, pp. 657–677, 5 pls., 4 figs., 1912. See no. 1114 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 89.

Ulrich, E. O.

1122. The Chattanoogan series with special reference to the Ohio shale problem: Am. Jour. Sci., 4th ser., vol. 34, pp. 157–183, 3 figs., August, 1912.

Umpleby, Joseph B.

1123. Note on the stratigraphy of east central Idaho: Washington Acad. Sci., Jour., vol. 2, no. 2, p. 49, January 10, 1912.

1124. An old erosion surface in Idaho; its age and value as a datum plane: Jour. Geology, vol. 20, no. 2, pp. 139–147, 3 figs., February–March, 1912.

1125. An old erosion surface in eastern Utah, its age and value in time determinations: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 4, pp. 109–110, February 19, 1912.

1126. Recent literature on economic geology: Econ. Geology, vol. 7, no. 7, pp. 711–714, October–November, 1912.

Recent literature on economic geology. See Knopf and Umpleby, nos. 598–600.

United States Geological Survey.

1127. Mineral resources of the United States, Calendar year, 1911; part I, Metals, 1018 pp., 16 figs.; part II, Nonmetals, 1224 pp., 9 pls., 14 figs., 1912.

Contains the following papers, mainly statistical in character, relating to the production, condition of the industry, etc., but also in some cases including notes on the geology and occurrence of the products treated:

PART I.

Mineral products of the United States: Review of conditions and output in 1910 and 1911, by Edward W. Parker, pp. 7–90.

Summary of mineral production in the United States in 1911, compiled by W. T. Thom, pp. 91–112.

Metals and metallic ores in 1910 and 1911, by H. D. McCaskey, pp. 113–118.

Iron ore, pig iron, and steel, by Ernest F. Burchard, pp. 119–174.

Iron-ore reserves of Michigan, by C. K. Leith, pp. 175–190.

Manganese and manganiferous ores, by Ernest F. Burchard, pp. 191–208.

Gold and silver, by H. D. McCaskey, pp. 211–254.

Copper, by B. S. Butler, pp. 255–313.

Lead, by C. E. Siebenthal, pp. 315–351.

Zinc, by C. E. Siebenthal, pp. 353–395.

Cadmium, by C. E. Siebenthal, pp. 399–401.

Gold, silver, copper, lead, and zinc in the Western States (mine production):

- Introduction, by H. D. McCaskey, pp. 403–406.
- Alaska, by A. H. Brooks, pp. 406–420.
- Arizona, by V. C. Heikes, pp. 420–462.
- California, by Charles G. Yale, pp. 462–505.
- Colorado, by Charles W. Henderson, pp. 505–569.
- Idaho, by C. N. Gerry, pp. 570–602.
- Montana, by V. C. Heikes, pp. 602–646.
- Nevada, by V. C. Heikes, pp. 646–702.
- New Mexico, by Charles W. Henderson, pp. 702–721.
- Oregon, by Charles G. Yale, pp. 721–733.
- South Dakota, by Charles W. Henderson, pp. 734–738.
- Texas, by Charles W. Henderson, pp. 739–740.
- Utah, by V. C. Heikes, pp. 740–777.
- Washington, by C. N. Gerry, pp. 778–788.
- Wyoming, by Charles W. Henderson, pp. 788–791.

Silver, copper, lead, and zinc in Central States (mine production), by J. P. Dunlop and B. S. Butler, pp. 793–872.

Gold, silver, copper, lead, and zinc in the Eastern States (mine production), by H. D. McCaskey, pp. 873–888.

Quicksilver, by H. D. McCaskey, pp. 889–921.

Bauxite and aluminum, by W. G. Phalen, pp. 923–939.

Tungsten, vanadium, uranium, titanium, molybdenum, nickel, cobalt, tantalum, tin, antimony, bismuth, and selenium, by Frank L. Hess, pp. 941–977.

Chromic iron ore, by W. C. Phalen, pp. 979–986.

Platinum and allied metals, by Waldemar Lindgren, pp. 987–1003.

PART II.

FUELS.

Coal; coke, by E. W. Parker, pp. 5–267.

Fuel briquetting, by E. W. Parker, pp. 269–278.

Natural gas, by D. T. Day and B. Hill, pp. 279–333.

Petroleum, by D. T. Day, pp. 335–480.

Peat, by C. A. Davis, pp. 481–484.

United States Geological Survey—Continued.

1127. Mineral resources of the United States, etc.—Continued.

STRUCTURAL MATERIALS.

Cement industry in the United States in 1911, by E. F. Burchard, pp. 485–519, 1 pl. (map).
Clay-working industries, by Jefferson Middleton, pp. 521–584.
Glass sand, other sand, and gravel, by E. F. Burchard, pp. 585–638.
Gypsum, by E. F. Burchard, pp. 639–644.
Lime, by E. F. Burchard, pp. 645–718.
Sand-lime brick, pp. 719–721.
Slate, by A. T. Coons, pp. 723–739.
Stone, by E. F. Burchard, 741–833, 7 pls. (maps).

ABRASIVE MATERIALS.

Abrasive materials, by W. C. Phalen, pp. 835–854.

CHEMICAL MATERIALS.

Arsenic, by F. L. Hess, pp. 855–856.
Borax, by H. S. Gale, pp. 857–866, 1 pl. (map).
Fluorspar and cryolite, by E. F. Burchard, pp. 867–875.
Phosphate rock, by F. B. Van Horn, pp. 877–888.
Potash salts, by W. C. Phalen, pp. 889–917.
Salt and bromine, by W. C. Phalen, pp. 919–936.
Sulphur, pyrite, and sulphuric acid, by W. C. Phalen, pp. 937–957.
Manufacture of sulphuric acid at Ducktown, Tenn., by F. B. Laney, pp. 958–964.
Barytes and strontium; mineral paints, by W. C. Phalen, pp. 965–993.

MISCELLANEOUS.

Asbestos, by J. S. Diller, pp. 995–1001.
Asphalt, related bitumens, and bituminous rock, by D. T. Day, pp. 1003–1021.
Feldspar and quartz, by Jefferson Middleton, pp. 1023–1030.
Fuller's earth, by Jefferson Middleton, pp. 1031–1035.
Gems and precious stones, by D. B. Sterrett, pp. 1037–1078.
Graphite, by E. S. Bastin, pp. 1079–1112.
Magnesite, by H. S. Gale, pp. 1113–1127.
Mica, by D. B. Sterrett, pp. 1129–1135.
Mineral waters, by G. C. Matson, pp. 1137–1174.
Concentration of mineral water in relation to therapeutic activity, by R. B. Dole, pp. 1175–1192.
Monazite and zircon, by D. B. Sterrett, pp. 1193–1196.
Talc and soapstone, by J. S. Diller, pp. 1197–1203.

1128. Miscellaneous analyses of coal samples from various fields of the United States: U. S. Geol. Survey, Bull. 471, pp. 629–655, 1912.

1129. Contributions to economic geology (short papers and preliminary reports), 1910; Part II, Mineral fuels: U. S. Geol. Survey, Bull. 471, 663 pp., 62 pls., 15 figs., 1912.

The papers in this bulletin have been entered under the individual authors.

Ussing, N. V.

1130. Geology of the country around Julianehaab, Greenland: Meddelelser om Grönland, H. 38, pp. 1–376, 18 pls., 32 figs., 1912; (Reprint) Copenhagen, Univ., Mus. Mineral. and Geol., Comm. géol., no. 2, 368 pp., 18 pls., 32 figs., 1911.

Ussing, N. V.—Continued.

1131. Beretning om den geologiske Ekspedition til Julianehaab Distrikt i Sommeren 1900: Meddelelser om Grönland, H. 38, pp. 377–426, 1 pl., 10 figs., 1912.

An account of a geological voyage to the Julianehaab district, Greenland, in 1900. Includes notes on the geology of the region.

Valiquette, J. H.

1132. Report on the Montreal quarries: Quebec (Province), Mines Branch, Rept. on mining operations during 1911, pp. 52–70, 5 pls., 1912.

Includes an account of the geologic formations in the vicinity of Montreal, Canada.

Vallance, John.

The Standard silver mine, B. C.: Canadian Min. Inst., Jour., vol. 14, pp. 212–214, 1912. See no. 1130 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 93.

Van Barneveld, Charles E.

1133. Iron mining in Minnesota: Minnesota, Univ., School of Mines, Exper. Sta., Bull. no. 1, 214 pp., 10 pls., 135 figs., 1912.

Van Horn, F. B.

1134. Fuller's earth in the South: Manufacturers Record, vol. 61, no. 7, pt. 2, pp. 69–70, February 22, 1912.

Mineral resources of the United States, 1911: Phosphate rock. See no. 1127.

Van Horn, Frank R.

1135. The occurrence of silver, copper, and lead ores at the Veta Rica mine, Sierra Mojada, Coahuila, Mexico: Am. Inst. Min. Eng., Bull., no. 68, pp. 867–881, 2 figs., August, 1912; Trans., vol. 43, pp. 219–233, 2 figs., 1913.

Van Tuyl, Francis M.

1136. The Salem limestone and its stratigraphic relations in southeastern Iowa: Iowa Acad. Sci., Proc., vol. 19, pp. 167–168, 1912; Abstract, Science, new ser., vol. 36, p. 569, October 25, 1912.

1137. The origin of the geodes of the Keokuk beds: Iowa Acad. Sci., Proc., vol. 19, pp. 169–172, 1912; Abstract, Science, new ser., vol. 36, p. 569, October 25, 1912.

1138. A study of the cherts of the Osage series of the Mississippian system: Iowa Acad. Sci., Proc., vol. 19, pp. 173–174, 1912; Abstract, Science, new ser., vol. 36, p. 569, October 25, 1912.

Discusses the origin of the cherts; these are considered to result from metasomatic replacement of limestone.

Visher, S. S.

A preliminary report upon the geography, geology, and biology of Mellette, Washabaugh, Bennett, and Todd counties, South Dakota. See Perisho and Visher, no. 843.

Volk, Ernest.

1139. Early man in America; thirty years of experience in searching for evidences of the antiquity of man in the Delaware Valley: Am. Mus. Jour., vol. 12, no. 5, pp. 181–185, 3 figs., May, 1912.

Von Engeln, O. D.

1140. In Missouri: Jour. Geog., vol. 10, no. 8, pp. 263–267, April, 1912.

Includes notes on physiographic features in the vicinity of Columbia, Mo.

Waggaman, William H.

1141. A report on the natural phosphates of Tennessee, Kentucky, and Arkansas: U. S., 62d Cong., 2d Sess., Sen. Doc. no. 190, pp. 49–77, 3 figs., 1912; U. S. Dept. Agr., Bur. Soils, Bull. no. 81, 36 pp., 4 pls., 3 figs., 1912.

1142. The phosphate deposits of the United States: Am. Fertilizer, vol. 37, no. 2, pp. 34–36, July 27, 1912.

Waitz, Paul.

1143. Notas preliminares relativas á un reconocimiento geológico por el curso del Atoyac (Rio Verde) de Oaxaca: Mexico, Inst. Geol., Parerg., t. 4, no. 1, pp. 2–32, 1912.

Gives geologic observations made in a reconnaissance along the Atoyac (Rio Verde) River in the State of Oaxaca, Mexico.

Walcott, Charles D.

1144. Cambrian geology and paleontology, II; No. 4, Cambrian faunas of China: Smithsonian Misc. Coll., vol. 57, no. 4, pp. 69–108, 4 pls., June 17, 1911.

Includes descriptions of the trilobites *Anomocare convexa* n. sp., *Coosia superba* n. gen. and sp., and *Coosia robusta* from the middle Cambrian of Alabama and Tennessee.

1145. Cambrian geology and paleontology, II; No. 6, Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata: Smithsonian Misc. Coll., vol. 57, no. 6, pp. 145–228, 11 pls., 3 figs., March 13, 1912.

1146. Cambrian geology and paleontology, II; No. 7, Cambro-Ordovician boundary in British Columbia with description of fossils: Smithsonian Misc. Coll., vol. 57, no. 7, pp. 229–237, 1 pl., March 8, 1912.

1147. Cambrian geology and paleontology, II; No. 8, The Sardinian Cambrian genus Olenopsis in America: Smithsonian Misc. Coll., vol. 57, no. 8, pp. 239–249, 1 pl., March 8, 1912.

1148. Cambrian geology and paleontology, II: No. 9, New York Potsdam-Hoyt fauna: Smithsonian Misc. Coll., vol. 57, no. 9, pp. 251–304, 13 pls., September 14, 1912.

Discusses the age relations and terminology of the Potsdam and Hoyt beds and the stratigraphic position of the fauna, and gives systematic descriptions of genera and species.

1149. Cambrian geology and paleontology, II; No. 10, Group terms for the lower and upper Cambrian series of formations: Smithsonian Misc. Coll., vol. 57, no. 10, pp. 305–307, September 16, 1912.

Proposes Waucoban to replace Georgian for lower Cambrian and St. Croixan for upper Cambrian instead of Saratogan.

1150. Cambrian Brachiopoda: U. S. Geol. Survey, Mon., vol. 51, pt. 1, 872 pp., 76 figs., pt. 2, 363 pp., 104 pls., 1912.

Includes a bibliography, list of synonymic references, tables of geographic and stratigraphic distribution, and list of localities; a discussion of the terminology and structural features of the shell, and of the evolution, classification, and distribution; and systematic descriptions of genera and species.

1151. Notes on fossils from limestone of Steeprock series, Ontario, Canada: Canada Geol. Survey, Mem. no. 28, pp. 16–22, 2 pls., 1912.

Describes from pre-Cambrian strata *Atikokania* n. gen. and *A. lawsoni* n. sp. and *A. irregularis* n. sp.

1152. Cambrian of the Kicking Horse Valley, B. C.: Canada Geol. Survey, Summ. Rept., 1911, pp. 188–191, 1912.

Walcott, Charles D.—Continued.

1153. Fossils of lower limestone of the Steeprock series: Abstract, Science, new ser., vol. 35, p. 315, February 23, 1912; Abstract (with discussion by A. P. Coleman), Geol. Soc. America, Bull., vol. 23, no. 4, p. 723, December 17, 1912.

1154. Illustrations of remarkable Cambrian fossils from British Columbia: Abstract, Science, new ser., vol. 35, p. 789, May 17, 1912.

See also no. 1275.

Wall, G. P.

1155. [Observations on the geology of the West Indies.]: Agric. Soc. Trinidad and Tobago, Proc., vol. 12, pt. 6, pp. 207–208, June, 1912.

Warren, Charles H.

1156. The ilmenite rocks near St. Urbain, Quebec; a new occurrence of rutile and sapphirine: Am. Jour. Sci., 4th ser., vol. 33, pp. 263–277, 1 fig., March, 1912.

Washington, Henry S.

1157. The constitution of some salic silicates: Am. Jour. Sci., 4th ser., vol. 34, pp. 555–571, December, 1912.

1158. A suggestion for mineral nomenclature: Am. Jour. Sci., 4th ser., vol. 33, pp. 137–151, February, 1912; Abstract, Geol. Soc. America, Bull., vol. 23, no. 4, p. 729, December 17, 1912.

Modifications of the quantitative system of classification of igneous rocks. See Cross and others, no. 240.

Watson, J. Wilbur.

A contribution to the geology and mineralogy of Graves Mountain, Georgia. See Watson and Watson, no. 1166.

Watson, Lawrence W.

1159. The geological age of Prince Edward Island: Nova Scotian Inst. Sci., Proc. and Trans., vol. 13, pt. 2, pp. 145–149, August 26, 1912.

Concludes that all the rocks of Prince Edward Island are of Permo-Carboniferous age, as against the opinion formerly held that part are of Triassic age.

Watson, Thomas Leonard.

1160. Administrative report of the state geologist for the biennial period 1910–1911: Virginia Geol. Survey, 25 pp., 1912.

1161. Economic products of the Virginia Coastal Plain: Virginia Geol. Survey, Bull. no. 4, pp. 223–263, 3 pls., 1912.

1162. An association of native gold with sillimanite: Am. Jour. Sci., 4th ser., vol. 33, pp. 241–244, 2 figs., March, 1912.

1163. Vanadium and chromium in rutile and the possible effect of vanadium on color: Washington Acad. Sci., Jour., vol. 2, no. 18, pp. 431–434, November 4, 1912.

1164. Kragerite, a rutile-bearing rock from Krageroe, Norway: Am. Jour. Sci., 4th ser., vol. 34, pp. 509–514, December, 1912.

Includes references to similar American rocks.

The physiography and geology of the Coastal Plain province of Virginia; Economic geology. See Clark and Miller, no. 192.

Watson, Thomas L., and **Hess**, Frank L.

1165. Zirconiferous sandstone near Ashland, Virginia, with a summary of the properties, occurrence, and uses of zircon in general: Virginia, Univ., Philos. Soc., Bull., Sci. ser., vol. 1, no. 11, pp. 267–292, 2 pls., 2 figs. (incl. map), July, 1912.

Watson, Thomas L., and Watson, J. Wilbur.

1166. A contribution to the geology and mineralogy of Graves Mountain, Georgia: Virginia, Univ., Philos. Soc., Bull., Sci. ser., vol. 1, no. 7, pp. 200–221, 2 figs., January, 1912.

Watts, Francis.

1167. Observations on West Indian geology: Agric. Soc. Trinidad and Tobago, Proc., vol. 12, pts. 1–2, pp. 35–37, January–February, 1912.

Weaver, Charles Edwin.

1168. Geology and ore deposits of the Index mining district: Washington Geol. Survey, Bull. no. 7, 96 pp., 7 pls., 1912.

The ores produce mainly copper.

1169. A preliminary report on the Tertiary paleontology of western Washington: Washington Geol. Survey, Bull. no. 15, 80 pp., 16 pls., 1912.

Webber, Morton.

1170. Cross-fractures and ore shoots: Min. and Sci. Press, vol. 104, pp. 380–381, March 9, 1912.

Weed, Walter Harvey.

1171. Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey, Prof. Paper 74, 262 pp., 41 pls., 109 figs., 1912.

Describes the general geology of the region, the character, occurrence, and relations of the igneous rocks, the geologic structure, the fracture system, the distribution, structure, and mineralogy of the ores, the genesis of the copper ores, and in detail the lodes and mining operations.

1172. Geysers. 29 pp., 22 figs. U. S., Dept. of the Interior, 1912.

1173. Literature of ore deposits in 1911: Min. and Sci. Press, vol. 104, pp. 35–36, January 6, 1912.

1174. Notes on the Miami copper district, Arizona: Min. and Eng. World, vol. 36, pp. 1043–1044, May 18, 1912.

1175. A plea for rational classification of ore deposits: Min. and Eng. World, vol. 36, p. 1088, May 25, 1912.

1176. Brief notes on the geology of the Ely district, Nevada: Min. and Eng. World, vol. 36, p. 1198, June 8, 1912.

1177. Is geology a success as a guide to ore deposits?: Min. and Eng. World, vol. 36, p. 1138, June 1, 1912; vol. 37, pp. 245–246, August 10, 1912.

Includes notes on the geology and copper ores of Bisbee, Arizona.

Wegemann, Carroll H.

1178. The Powder River oil field, Wyoming: U. S. Geol. Survey, Bull. 471, pp. 56–75, 1 pl. (map), 1 fig., 1912.

1179. The Sussex coal field, Johnson, Natrona, and Converse counties, Wyoming: U. S. Geol. Survey, Bull. 471, pp. 441–471, 9 pls. (maps and sections), 1912.

1180. Planetable methods as adapted to geologic mapping: Econ. Geology, vol. 7, no. 7, pp. 621–637, 1 pl., October–November, 1912.

Wegener, A.

Die glaciologischen Beobachtungen der Danmark-Expedition. See Koch and Wegener, no. 603.

Welsh, T. W. B., and Stewart, C. A.

1181. Note on the effect of calcite gangue on the secondary enrichment of copper veins (discussion): Econ. Geology, vol. 7, no. 8, pp. 785–787, December, 1912.

Wentworth, Irving H.

1182. The San Nicolas mining district, San Nicolas, Tamaulipas, Mexico: Am. Inst. Min. Eng., Bull., no. 68, pp. 843–852, 3 figs., August, 1912; Trans., vol. 43, pp. 304–313, 3 figs., 1913.

Westgate, Lewis G.

1183. The geological progress of twenty-five years: Ohio State Acad. Sci., Proc., vol. 6, pt. 1, pp. 20–42, June, 1912.

Westgate, L. G., and **Branson**, E. B.

1184. The Cenozoic history of the Wind River Mountains, Wyoming: Abstracts. Science, new ser., vol. 35, p. 318, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 739, December 17, 1912.

Wheeler, H. A.

1185. Developments in the Illinois oil fields: Assoc. Eng. Soc., Jour., vol. 48, no. 2, pp. 68–77, February, 1912.

Wherry, Edgar T.

1186. Crystallographic tables: Science, new ser., vol. 35, pp. 820–821, May 24, 1912.

1187. A new occurrence of carnotite: Am. Jour. Sci., 4th ser., vol. 33, pp. 574–580, June, 1912.

Describes the composition and geologic relations of carnotite occurring near Mauch Chunk, Pa.

1188. The Triassic of Pennsylvania: Abstract, Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 2, p. 156, May, 1912.

1189. Apparent sun-crack structures and ringing-rock phenomena in the Triassic diabase of eastern Pennsylvania: Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 2, pp. 169–172, 1 pl., May, 1912.

1190. Silicified wood from the Triassic of Pennsylvania: Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 2, pp. 366–372, 2 pls., 1 fig., July, 1912.

1191. Age and correlation of the "New Red" or Newark group in Pennsylvania: Acad. Nat. Sci. Philadelphia, Proc., vol. 64, pt. 2, pp. 373–379, 1 fig., July, 1912.

A Mississippian delta. See Branson, no. 103.

Whinery, S.

1192. Clinton iron-ore deposits in Kentucky and Tennessee: Am. Inst. Min. Eng., Bull. no. 70, pp. 1057–1058, October, 1912.

White, A. E.

The pig-iron industry of Michigan. See Allen and others, no. 13.

White, David.

1193. The characters of the fossil plant Gigantopteris Schenk and its occurrence in North America: U. S. Nat. Mus., Proc., vol. 41, pp. 493–516, 7 pls., February 8, 1912.

1194. Age of the Worcester phyllite: Washington Acad. Sci., Jour., vol. 2, no. 5, pp. 114–118, March 4, 1912.

Describes the character and occurrence of plant remains by which the age is determined to be Carboniferous.

1195. [Formation of limestone near tide level]: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 14, p. 357, August 19, 1912.

1196. Resins in Paleozoic coals: Abstracts, Science, new ser., vol. 35, p. 312, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 728, December 17, 1912.

A Mississippian delta. See Branson, no. 103.

Abstract of "Geology and mineral resources of the Peoria quadrangle, Illinois." See Udden, no. 1117.

Whiteside, F. W.

1197. The Trinidad district in Colorado: Coal Age, vol. 1, pp. 632–635, 6 figs., February 24, 1912.

Includes notes on the geology of the Trinidad coal field, Colorado.

1198. Central coal fields in Colorado: Coal Age, vol. 2, no. 1, pp. 2–5, 6 figs., July 6, 1912.

Whitlock, H. P.

1199. Recent mineral occurrences in New York City and vicinity: New York State Mus., Bull. 158, pp. 183–187, 7 figs., 1912.

1200. Crystallographic tables: Science, new ser., vol. 35, pp. 819–820, May 24, 1912.

Whitney, Milton, and others.

1201. Field operations of the Bureau of Soils, 1909. U. S. Dept. Agr., Bur. Soils, Eleventh Report. 1740 pp., 25 pls., 58 figs., and 53 soil maps (in separate case). Washington, 1912.

Contains soil surveys of the following areas:
Alabama, Baldwin County, pp. 705–774.
Chambers County, pp. 775–800.
Coffee County, pp. 801–847.
Hale County, pp. 677–703.
Tallapoosa County, pp. 645–676.
California, Marysville area, pp. 1689–1740.
Woodland area, pp. 1635–1687.
Florida, Marianna area, pp. 619–644.
Georgia, Franklin County, pp. 533–550.
Hancock County, pp. 551–573.
Pike County, pp. 575–601.
Tift County, pp. 603–618.
Louisiana, Lincoln Parish, pp. 921–949.
Maine, Orono area, pp. 41–74.
Maryland, Anne Arundel County, pp. 271–308.
Minnesota, Rice County, pp. 1269–1303.
Mississippi, Clay County, pp. 849–885.
Scranton area, pp. 887–920.
Missouri, Atchison County, pp. 1305–1336.
Cedar County, pp. 1337–1366.
Cooper County, pp. 1367–1399.
Nevada, Fallon area, pp. 1477–1516.
New Hampshire, Nashua area, pp. 75–104.
New York, Washington County, pp. 105–159.
North Carolina, Gaston County, pp. 345–373.
Lake Mattamuskeet area, pp. 375–387.
Pitt County, pp. 389–419.
Scotland County, pp. 421–448.
Ohio, Auglaize County, pp. 1131–1148.
Oregon, Marshfield area, pp. 1601–1634.
Pennsylvania, Berks County, pp. 161–203.
southwestern, reconnaissance survey, pp. 205–269.
South Carolina, Anderson County, pp. 449–471.
Conway area, pp. 473–502.
Saluda County, pp. 503–531.
South Dakota, western, reconnaissance survey, pp. 1401–1476.
Tennessee, Sumner County, pp. 1149–1173.
Texas, Grayson County, pp. 951–983.
Morris County, pp. 985–1004.
south, reconnaissance survey, pp. 1029–1129.
Titus County, pp. 1005–1027.
Virginia, Campbell County, pp. 309–343.
Washington, Puget Sound Basin, reconnaissance survey, pp. 1517–1600.
West Virginia, Spencer area, pp. 1175–1202.
Wisconsin, Marinette County, reconnaissance survey, pp. 1233–1267.
Waushara County, pp. 1203–1231.

Wickham, H. F.

1202. A report on some recent collections of fossil Coleoptera from the Miocene shales of Florissant [Colorado]: Iowa, Univ., Lab. Nat. Hist., Bull.; vol. 6, no. 3, pp. 3–38, 8 pls., May 18, 1912.

Includes descriptions of a number of new genera and species.

1203. On some fossil rhynchophorous Coleoptera from Florissant, Colorado: Am. Mus. Nat. Hist., Bull., vol. 31, pp. 41–55, 4 pls., 1912.

Wieland, G. R.

1204. A study of some American fossil cycads; Part VI, On the smaller flower buds of Cycadeoidea: Am. Jour. Sci., 4th ser., vol. 33, pp. 73–91, 23 figs., February, 1912.

1205. Note on the dinosaur-turtle analogy: Science, new ser., vol. 36, pp. 287–288, August 30, 1912.

Williams, Edward H., jr.

1206. The heating in the Culebra cut [Canal Zone]: Science, new ser., vol. 35, pp. 892–893, June 7, 1912.

Discusses the spontaneous oxidation of pyrite.

Williams, Henry Shaler.

1207. Some new Mollusca from the Silurian formations of Washington County, Maine: U. S. Nat. Mus., Proc., vol. 42, pp. 381–398, 2 pls., 1912.

1208. Ralph Stockman Tarr [1864–1912]: Am. Jour. Sci., 4th ser., vol. 33, pp. 515–516, May, 1912.

1209. Correlation of the Paleozoic faunas of the Eastport quadrangle, Maine: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 349–356, July 15, 1912.

Williams, S. R.

1210. Some principles of zoology as illustrated by the fossil remains of southwestern Ohio: Miami Bull., Oxford, Ohio, ser. 8, no. 7, 20 pp., 4 pls., January, 1910.

Includes notes on the occurrence of the fossils of the Richmond formation in the vicinity of Oxford, Ohio.

Williams, Merton Y.

1211. Geology of Arisaig-Antigonish district, Nova Scotia: Am. Jour. Sci., 4th ser., vol. 34, pp. 242–250, September, 1912.

Willis, Bailey.

1212. Index to the stratigraphy of North America: U. S. Geol. Survey, Prof. Paper 71, 894 pp., 1 pl. [geol. map, in 4 sheets in separate case], 19 figs. (outline maps), 5 inserts, 1912.

A compilation of the data, published and unpublished, used in the preparation of the colored geologic map (77 x 60 inches, scale 1 : 5,000,000).

Williston, Samuel Wendell.

1213. Ten years' progress in vertebrate paleontology; evolutionary evidences: Geol. Soc. America, Bull., vol. 23, no. 2, pp. 257–262, June 1, 1912.

1214. Restoration of Limnoscelis, a Cotylosaur reptile from New Mexico: Am. Jour. Sci., 4th ser., vol. 34, pp. 457–468, November, 1912.

1215. Primitive reptiles: Jour. Morphology, vol. 23, no. 4, pp. 637–666, 1 fig., December 20, 1912.

Williston, S. W., and Case, E. C.

1216. The Permo-Carboniferous of northern New Mexico: Jour. Geology, vol. 20, no. 1, pp. 1–12, 2 figs. (maps), 1912.

Willmott, A. B.

The undeveloped iron resources of Canada: Canadian Min. Inst., Jour., vol. 14, pp. 236–258, 1912. See no. 1215 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 99.

Wilson, Alfred W. G.

1217. Pyrites in Canada, its occurrence, exploitation, dressing and uses: Canada, Dept. Mines, Mines Branch, 202 pp., 27 pls., 29 figs., 1 map, 1912.

1218. Copper and pyrites: Canada, Dept. Mines, Mines Branch, Summ. Rept., 1911, pp. 90–94, 1912.

Diamond drilling at Point Mamainse, Province of Ontario: Introductory. See Lane, no. 628.

Wilson, Eugene B.

1219. Formation of magmas: Mines and Minerals, vol. 33, p. 115, September, 1912.

Some notes on pyrite and marcasite: Canadian Min. Inst., Jour., vol. 14, pp. 310–315, 1912. See no. 1218 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524, p. 99.

Wilson, Morley E.

1220. Geology and economic resources of the Larder Lake district, Ontario, and adjoining portions of Pontiac County, Quebec: Canada, Geol. Survey, Mem. 17, 62 pp., 11 pls., 5 figs., 2 maps, 1912.

1221. Kewagama Lake map area, Pontiac and Abitibi, Quebec: Canada Geol. Survey, Summ. Rept., 1911, pp. 273–279, 1912.

Wilson, W. J.

1222. [Report of the] Paleontological division; paleobotany: Canada Geol. Survey, Summ. Rept., 1911, pp. 358–359, 1912.

Winchell, Alexander N.

1223. Brun's new data on volcanism: Econ. Geology, vol. 7, no. 1, pp. 1–14, January, 1912.

1224. Geology of the National mining district, Nevada: Min. and Sci. Press, vol. 105, pp. 655–659, 4 figs., November 23, 1912.

Notes on the Blue Bird mine [Wickes, Montana]. See Winchell and Winchell, no. 1227.

Winchell, Horace V.

1225. Secondary sulphide enrichment: Eng. and Min. Jour., vol. 93, pp. 364–367, February 17, 1912.

1226. The St. Helens mining district, Washington: Am. Inst. Min. Eng., Bull. no. 70, pp. 1037–1044, 1 fig., October, 1912.

Describes the geology and mineral conditions of the district.

Winchell, H. V., and **Winchell**, A. N.

1227. Notes on the Blue Bird mine [Wickes, Montana]: Econ. Geology, vol. 7, no. 3, pp. 287–294, 2 figs., April–May, 1912.

Describes the general features and mineralization of the mine, and particularly the abundant tourmaline.

Winchell, Newton H.

1228. Memoir of Christopher Webber Hall: Geol. Soc. America, Bull., vol. 23, no. 1, pp. 28–30, 1 pl. (port.), March 14, 1912.

Includes a list of his writings.

Winchell, Newton H.—Continued.

1229. Progress of opinion as to the origin of the Lake Superior iron ores: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 317–328, 1 fig., July 15, 1912.

1230. Saponite, thalite, greenalite, greenstone: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 329–332, July 15, 1912.

Discusses the relations and origin of these minerals associated with the Lake Superior iron ores.

Winchester, Dean E.

1231. The Lost Spring coal field, Converse County, Wyoming: U. S. Geol. Survey, Bull. 471, pp. 472–515, 5 pls. (maps and sections), 1912.

Coal fields of the Wind River region. See Woodruff and Winchester, no. 1246.

Winstanley, J. B.

Bibliography of the geology, paleontology, mineralogy, petrology, and mineral resources of Oregon. See Henderson and Winstanley, no. 445.

Wittich, Ernst.

1232. Strandlinien an der Südküste von Niederkalifornien: Globus, Bd. 97, no. 24, p. 379, June 30, 1910.

Describes elevated coast lines in Lower California. Includes notes on the geology of the region.

1233. Ueber Meeresschwankungen an der Küste von Kalifornien: Deutsch. Geol. Ges., Zeits., Monatsber. no. 11, pp. 505–512, 1912.

Presents evidences of a recent rising of the southern coast of southern California and of Lower California

Wittich, Ernst, and **Pastor y Giraud**, Antonio.

1234. Riesengipskristalle aus Chihuahua, Nord-Mexiko: Centralbl. Mineralogie, no. 23, pp. 731–733, December 1, 1912.

Describes the occurrence of mammoth crystals of gypsum in the Naica mine, State of Chihuahua, Mexico.

Wittich, Lucius L.

1235. Barytes in Missouri: Mines and Minerals, vol. 33, pp. 95–97, 3 figs., September, 1912.

1236. Iron mining in Missouri: Mines and Minerals, vol. 33, pp. 227–228, 4 figs., November, 1912.

Wolff, John E.

1237. A new chlorite from northern Wyoming: Am. Jour. Sci., 4th ser., vol. 34, pp. 475–476, November, 1912.

Wood, H. O.

1238. The registration of earthquakes at the Berkeley station from October 30, 1910, to March 31, 1911: California, Univ., Seismographic Stations, Bull. no. 1, pp. 1–10, January 2, 1912.

1239. The registration of earthquakes at the Berkeley station from April 1 to September 30, 1911, and at the Lick Observatory station from May 23 to September 30, 1911: California, Univ., Seismographic Stations, Bull., no. 2, pp. 11–48, September 5, 1912.

1240. The registration of earthquakes at the Berkeley station and at the Lick Observatory station from October 1, 1911, to March 31, 1912: California, Univ., Seismographic Stations, Bull., no. 3, pp. 49–67, October 19, 1912.

Wood, H. O.—Continued.

1241. On the region of origin of the central Californian earthquakes of July, August, and September, 1911: Seism. Soc. America, Bull., vol. 2, no. 1, pp. 31–39, 1 fig., 1912.

1242. Seismographic bookkeeping: Seism. Soc. America, Bull., vol. 2, no. 2, pp. 118–123, June, 1912.

Woodbridge, Dwight E.

Exploration of Cuban iron-ore deposits: Am. Inst. Min. Eng., Trans., vol. 42, pp. 138–152, 4 figs., 1912. See no. 1240 of the bibliography for 1911, U. S. Geol. Survey, Bull. 524.

Woodruff, E. G.

1243. Geology of the San Juan oil field, Utah: U. S. Geol. Survey, Bull. 471, pp. 76–104, 2 pls. (maps), 1 fig., 1912.

1244. Marsh gas along Grand River near Moab, Utah: U. S. Geol. Survey, Bull. 471, p. 105, 1912.

1245. The coal resources of Gunnison Valley, Mesa and Delta counties, Colorado: U. S. Geol. Survey, Bull. 471, pp. 565–573, 1 pl. (map and sections), 1912.

Woodruff, E. G., and Winchester, Dean E.

1246. Coal fields of the Wind River region, Fremont and Natrona counties, Wyoming: U. S. Geol. Survey, Bull. 471, pp. 516–564, 9 pls. (maps and sections), 2 figs., 1912.

Woodworth, J. B.

1247. Dynamic and structural geology: American Year Book, 1911, pp. 581–584, 1912.

Reviews the progress during the year 1911, citing the more important publications.

1248. Harvard seismographic station. Third annual report for the year, 1 August, 1910–31 July, 1911: Harvard Coll., Mus. Comp. Zool., Bull., vol. 55, no. 1 (Geol. ser., vol. 9, no. 1), pp. 3–23, February, 1912.

1249. Boulder beds of the Caney shale at Talihina, Oklahoma: Geol. Soc. America, Bull., vol. 23, no. 3, pp. 457–462, September 25, 1912. Abstract, Science, new ser., vol. 35, p. 319, February 23, 1912.

Discusses the occurrence of striated boulders in the Caney shales, the criteria for determining glaciated stones, and climate during the Carboniferous.

Woolsey, Lester Hood.

Geology and ore deposits of the Park City district, Utah. See Boutwell, no. 92.

Wooton, Paul.

1250. Louisiana salt mines: their operation and output: Min. and Eng. World, vol. 36, pp. 401–402, 2 figs., February 17, 1912.

1251. History and development of Louisiana's oil fields: Min. and Eng. World, vol. 36, pp. 1296–1298, 2 figs., June 22, 1912.

Wright, Fred. Eugene.

1252. The methods of petrographic-microscopic research; their accuracy and range of application: Abstract, Washington Acad. Sci., Jour., vol. 2, no. 3, pp. 83–84, February 4, 1912.

1253. Microscopical petrography from the quantitative viewpoint: Jour. Geol., vol. 20, no. 6, pp. 481–501, 1912.

Wright, Fred. Eugene—Continued.

1254. Granularity limits in petrographic-microscopic work: Abstracts, Science, new ser., vol. 35, p. 312, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 4, p. 726, December 17, 1912.

Wright, G. Frederick.

1255. Origin and antiquity of man. ix, 547 pp., illus. Oberlin, Ohio, Bibliotheca Sacra Company, 1912.

1256. Postglacial erosion and oxidation: Abstracts, Science, new ser., vol. 35, pp. 316–317, February 23, 1912; Geol. Soc. America, Bull., vol. 23, no. 2, pp. 277–296, 1 pl., 6 figs., June 27, 1912.

Discusses the duration of postglacial, glacial, and interglacial periods in the light of observations on erosion in northern Ohio, and the oxidation of drift materials.

Wright, W. J.

1257. Lahave Valley and Starrs Point, Nova Scotia: Canada Geol. Survey, Summ. Rept., 1911, pp. 341–342, 1912.

Gives notes on the geology of part of Lunenburg County, Nova Scotia.

Young, G. A.

1258. Bathurst district, New Brunswick: Canada Geol. Survey, Mem. no. 18, 96 pp., 1 fig., 2 maps, 1911.

Describes the general geology, the occurrence, relations, and character of Ordovician, Silurian, Devonian, and Carboniferous formations, the geologic structure and history, and the character, occurrence, and origin of iron deposits.

1259. Geology of the Moncton map area, Westmorland and Albert counties, New Brunswick: Canada Geol. Survey, Summ. Rept., 1911, pp. 309–321, 1912.

Youngs, L. J.

Ueber die Aenderungen des optischen Achsenwinkels in Gips mit der Temperatur. See Kraus and Youngs, no. 609.

Zapffe, Carl.

1260. The effects of a basic igneous intrusion on a Lake Superior iron-bearing formation: Econ. Geology, vol. 7, no. 2, pp. 145–178, February–March, 1912.

Describes the geology of the Gunflint district and the composition and character of the Keewatin greenstone, the iron-bearing formation, the Keweenawan rocks, and the Logan sills, and discusses the original composition of the rocks and the changes produced by the intrusion.

1261. The geology of the St. Helens mining district of Washington: Econ. Geology, vol. 7, no. 4, pp. 340–350, June, 1912.

Ziegler, Victor.

1262. The siliceous oolites of central Pennsylvania: Am. Jour. Sci., 4th ser., vol. 34, pp. 113–127, 14 figs., August, 1912.

Describes the occurrence and geologic relations of siliceous oolites and their petrographic characters, and discusses their origin.

Zimányi, K.

1263. Ueber Pyritkrystalle von Spanish Peaks in Colorado: Zeits. Krystal., Bd. 51, H. 2, pp. 146–148, 1 fig., 1912.

Describes pyrite crystals from Spanish Peaks in Colorado.

Anonymous.

1264. Obituary, E. R. Buckley: Min. and Metal. Soc. America, Bull. no. 45 (vol. 5, no. 2), pp. 37–38, February, 1912.

1265. Ernest Robertson Buckley [obituary notice]: Min. and Eng. World, vol. 36, p. 306, port., February 3, 1912.

1266. W. J. McGee: Eng. and Min. Jour., vol. 94, p. 484, September 14, 1912.

1267. Obituary notice, W. J. McGee: Am. Jour. Sci., 4th ser., vol. 34, p. 496, November, 1912.

1268. Ralph Stockman Tarr [1864–1912]: Am. Geog. Soc., Bull., vol. 44, no. 4, pp. 283–285, April, 1912.

1269. David White: Eng. and Min. Jour., vol. 94, p. 1066, 1 fig. (port.), December 7, 1912.

1270. Patricia district, Ontario: Eng. and Min. Jour., vol. 94, pp. 973–974, 1 fig. (map), November 23, 1912.

1271. Development of the Green River oil fields [Utah]: Salt Lake Min. Rev., vol. 14, no. 4, pp. 11–14, 3 figs., May 30, 1912.

Includes notes on the geology of the field.

1272. Seismological notes: Seism. Soc. America, Bull., vol. 2, no. 3, pp. 209–212, September, 1912.

1273. Volcanoes of Alaska: Nat. Geog. Mag., vol. 23, no. 8, pp. 824–832, 11 figs., August, 1912.

Describes phenomena connected with the eruption of Katmai volcano, Alaska.

1274. International catalogue of scientific literature; G (Mineralogy, including petrology and crystallography); H (Geology); J (Geography); K (Paleontology). Annual issues, 1–10, 1901–1910. London, Royal Society, 1902–1912.

1275. Expeditions organized or participated in by the Smithsonian Institution in 1910 and 1911; Studies in Cambrian geology and paleontology in the Canadian Rockies: Smithsonian Misc. Coll., vol. 59, no. 11, pp. 39–45, 5 figs., July 17, 1912.

Includes notes on the occurrence of Cambrian fossils.

CLASSIFIED SCHEME OF SUBJECT HEADINGS.

1. GENERAL.

Associations, meetings; Addresses; History; Philosophy; Biography; Bibliography; Educational; Text-books.

Classification; Nomenclature; Cartography; Technique; Fieldwork; Surveys; Borings.

Geochemistry; Chemical analyses (list); Atmosphere; Radioactivity.

Experimental investigations; Miscellaneous.

2. REGIONAL.

The States of the Union, Alabama, etc.; the Provinces of Canada, Alberta, etc.; Greenland; Mexico; the countries of Central America; the West Indies, and the single islands; the Hawaiian Islands.

3. ECONOMIC.

Ore deposits, origin; Contact phenomena.

Gold; Placers; Black sands; Silver; Quicksilver; Nickel; Cobalt; Copper; Lead; Zinc; Iron; Magnetite; Manganese; Tin; Aluminum; Bauxite; Antimony; Bismuth; Tungsten; Wolframite; Vanadium; Uranium; Carnotite ores; Molybdenum; Molybdenite; Titanium; Rutile; Platinum; Iridium; Rhodium; Palladium; Cadmium; Monazite; Rare earths; Tantalum; Selenium; Tellurium; Zircon.

Coal; Anthracite; Coke; Peat; Lignite; Bituminous rock; Natural gas; Petroleum; Oil shales; Asphalt; Albertite; Gilsonite; Grahamite; Ozokerite.

Stone; Building stone; Granite; Bluestone; Limestone; Lime; Marble; Onyx; Sandstone; Clay; Kaolin; Bentonite; Fire clay; Ganister; Slate; Shale; Marl; Sand; Glass sand; Sand-lime brick; Gravel; Cement and cement materials; Concrete materials; Road materials; Trap; Steatite; Soapstone; Talc; Serpentine.

Precious stones; Diamonds; Sapphires; Turquoise; Tourmaline.

Abrasive materials; Corundum; Emery; Garnet; Diatomaceous earth; Tripoli; Volcanic ash; Millstones; Novaculite.

Asbestos; Feldspar; Mica; Quartz; Gypsum; Graphite; Fuller's earth; Infusorial earth; Magnesite; Mineral paint; Chromium; Chromite; Chromic iron ore; Fluorspar; Barite; Barytes; Strontium; Arsenic; Pyrite; Sulphur; Sulphate of soda; Cryolite; Phosphorus; Phosphate; Apatite; Potash; Alunite; Glauconite; Borax; Bromine; Salt; Natron deposits.

4. DYNAMIC AND STRUCTURAL.

Earth, genesis of; Earth, age of; Earth, interior of; Earth, temperature of.

Volcanism; Volcanoes; Earthquakes; Seismology; Seismographs; Mud volcanoes.

Isostasy; Orogeny; Changes of level.

Magmas; Intrusions; Dikes; Laccoliths; Metamorphism; Contact phenomena.

Deformation; Folding; Faulting; Unconformities.

Conglomerates; Concretions; Stalactites; Jointing; Cleavage.

Sedimentation; Denudation; Erosion; Caves; Sink holes; Erratic bowlders; Weathering; Wind work; Dunes; Loess; Landslides.

Glaciers; Glacial erosion; Eskers; Kames; Moraines; Kettle holes.

Drainage changes.

5. PHYSIOGRAPHIC.

Geomorphy; Relief maps.

Valleys; Cirques; Deserts; Dunes; Deltas; Alluvial fans; Eskers; Kames; Mounds, natural; Natural bridges; Sink holes; Karsts.

Lakes; Swamps; Marshes; Everglades; Terraces; Beaches; Shore lines; Rivers; Meanders; Falls; Springs.

6. HISTORIC OR STRATIGRAPHIC.

Geologic history; Geologic time; Paleogeography; Paleogeographic maps; Paleoclimatology.

Geologic maps; Geologic formations described (list).

Pre-Cambrian; Paleozoic (undifferentiated); Cambrian; Ordovician; Silurian; Devonian; Carboniferous; Triassic; Jurassic; Cretaceous; Tertiary; Quaternary; Recent; Glacial geology; Glaciation; Glacial lakes; Ice ages.

7. PALEONTOLOGY.

Geographic distribution; Evolution; Restorations.

Vertebrata; Man, fossil; Mammalia; Aves; Reptilia; Amphibia; Pisces; Footprints, fossil.

Invertebrata; Arthropoda; Crustacea; Trilobita; Ostracoda; Insecta; Arachnida; Myriapoda.

Mollusca; Cephalopoda; Gastropoda; Pelecypoda.

Molluscoidea; Brachiopoda; Bryozoa; Vermes.

Echinodermata; Echinoidea; Asteroidea; Crinoidea; Crystoidea.

Cœlenterata; Anthozoa; Hydrozoa; Graptolites.

Protozoa; Spongida; Foraminifera.

Paleobotany; Diatoms.

Problematica.

8. PETROLOGY.

Rocks, origin; Rocks, structural features; Rocks described (list); Igneous and volcanic rocks; Rock-forming minerals; Lava; Oolite; Pebbles.

9. MINERALOGY.

Minerals described (list); Crystallography; Pseudomorphism; Paragenesis of minerals; Rock-forming minerals; Meteorites.

10. UNDERGROUND WATER.

Mine waters; Thermal waters; Geysers; Springs; Mineral waters.

11. SOILS.

INDEX.

[The numbers refer to entries in the bibliography.]

Abrasive materials.
United States: U. S. G. S., 1127.

Addresses.
Applied geology: Brooks, 110.
Geophysical research: Day, 274.
Recent developments in geology: Butler, 143.
Relation of geography to geology: Davis, 271.
Vertebrate life of Canada: Lambe, 625.

Agrogeology.
Florida, soils: Sellards, 961.

Alabama.
General.
Carboniferous coal pebbles: Prouty, 874.
Economic.
Coosa coal field: Prouty, 873.
Fayette gas field: Munn, 785.
Iron: Phillips, 853.
Mineral production, 1910: Abele, 1.
Stratigraphic.
Coosa coal fields: Prouty, 873.
Dolomite formations: Butts, 148.
Fayette field: Munn, 785.
Paleontology.
Cambrian trilobites: Walcott, 1144.
Echinids, Tertiary: Stefanini, 1028.
Mosasauroid reptile from Cretaceous: Gilmore, 365.
Mineralogy.
Evansite: Grasty, 393.

Alaska.
General.
Alatna-Noatak region: Smith, 998.
Alaska Peninsula: Atwood, 31.
Geology of boundary between Porcupine and Yukon rivers: Cairnes, 150.
Mineral resources, 1911: Brooks *et al.*, 115.
Porcupine to Arctic boundary: Maddren, 712.
Prince William Sound: Grant and Higgins, 392.
Railway routes: Brooks, 113.
Volcanic ashes from Kodiak: Fry. 342.
Economic.
Bonnifield region: Capps, 170.
Bremner River district: Moffit, 770.

Alaska—Continued.
Economic—Continued.
Chistochina district: Moffit, 769.
Chitina copper district: Moffit, 771.
Eagle River region: Knopf, 594.
Gold deposits, Valdez: Brooks, 114.
Gold placers, Fortymile, Eagle, and Seventy-mile River districts: Porter, 866.
Fairbanks and Circle districts: Ellsworth, 309.
Woodchopper and Fourth of July creeks: Prindle and Mertie, 869.
Yentna district: Capps, 171.
Iliamna region: Martin and Katz, 721.
Katalla oil field: Thompson, 1081.
Kenai Peninsula, mineral resources: Brewer, 106.
Seward-Sunrise region, gold deposits: Johnson, 549.
Matanuska Valley: Martin and Katz, 722.
Mining industry, 1911: Brooks, 112.
Prince William Sound: Grant and Higgins, 392.
Rampart and Hot Springs regions: Eakin, 297.
Ruby placer district: Maddren, 711.
Seward Peninsula: Smith, 999.
Sitka district: Knopf, 595.
Taral River district: Moffit, 770.
Valdez Creek district: Moffit, 769; Storm, 1050.
Dynamic and structural.
Alaska Range, glaciation: Capps, 172.
Earthquakes, Yakutat Bay: Tarr and Martin, 1066.
Glaciers: Tarr, 1063.
coastal: Martin, 723.
Yakutat Bay: Tarr, 1065.
Katmai eruption: Clark, 189; Dailey, 249.
Volcanic ash, fall on Seward Peninsula: Smith, 1000.
Volcanoes: Anon., 1273.
Physiographic.
Differential erosion and equiplanation: Cairnes, 153.
Glaciers along coast: Martin, 723.
Northwestern Alaska, glaciation: Smith, 997.

Alaska—Continued.
Stratigraphic.
Alatna-Noatak region: Smith, 998.
Bonnifield region: Capps, 170.
Eagle River region: Knopf, 594.
Glacial deposits: Tarr and Martin, 1067.
Gulkana-Susitna region: Moffit, 769.
Iliamna region: Martin and Katz, 721.
Koyukuk-Kobuk region: Smith, 1001.
Matanuska Valley: Martin and Katz, 722.
Mesozoic stratigraphy: Martin, 720.
Northwestern Alaska, glaciation: Smith, 997.
Orange group: Cairnes, 154.
Porcupine to Arctic boundary: Maddren, 712.
Sitka district: Knopf, 595.
Paleontology.
Mytilus middendorfii: Gratacap, 395.
Tertiary freshwater Mollusca: Hannibal, 427.
Triassic fossils from southeastern Alaska: Atwood, 29.
Alatna-Noatak region, Alaska: Smith, 998.
Albany terranes, Vermont: Richardson and Collister, 905.
Alberta.
Economic.
Blairmore area: Leach, 643.
Clay and shale deposits: Ries and Keele, 916.
Coal fields: Denis, 277; Dowling, 286; Fullerton, 347.
Roche Miette area, Jasper Park: Dowling, 285.
Stratigraphic.
Blairmore area: Leach, 643.
Roche Miette area, Jasper Park: Dowling, 285.
Turtle Mountain, Frank: Daly *et al.*, 257.
Paleontology.
Dinosaur from Edmonton Cretaceous: Brown, 120.
Dinosaurs: Matthew, 733.
Olenopsis from Cambrian: Walcott, 1147.
Widdringtonites: Berry, 69.
Albertite.
New Brunswick: Milner, 766.
Algonkian. *See* Pre-Cambrian.
Allosaurus: Osborn, 811.
Alma district, Park Co., Colo.: Patton *et al.*, 834.
Aluminum.
Tennessee: Ashley, 28.
United States: U. S. G. S., 1127.
Alunite.
Colorado, Rosita Hills: Cross, 236.
Utah, Marysville: Butler and Gale, 141.
Ammonites. *See* Cephalopoda.
Amphibia.
Carboniferous, Mazon Creek, Illinois: Moodie, 775.
Diplocaulia, Texas: Moodie, 773.
Diplocaulus: Huene, 521.
Eryops: Huene, 520.
Jurassic frog, Wyoming: Moodie, 776.
Lateral line system: Moodie, 772.
Ten years' progress: Case, 176.
Analcite, Foote and Bradley, 331.
Analyses, chemical. *See list, p. 165.*
Anhydrite, origin: Rogers, 924; Jones, 559.
Animikie. *See* Pre-Cambrian.
Antigua.
General: Guppy, 411, 412, 413; Watts, 1167.
Antimony.
United States: U. S. G. S., 1127.
Yukon, Wheaton district: Cairnes, 149.
Apatite.
Quebec, Ottawa Valley: Stansfield, 1018.
Apishapa quadrangle, Colorado: Stose, 1056.
Arachnida.
Nebraska, Eurypterids: Barbour, 45.
Archean. *See* Pre-Cambrian.
Arctic regions.
Paleontology.
Triassic, Eureka Sound: Kitti, 590.
Petrology.
Petrographic results, Fram Expedition: Bugge, 127.
Arizona.
Economic.
Bisbee district: Weed, 1177.
Castle Dome lead district: Nevius, 797.
Copper Butte: Probert, 870.
Copper deposits: Tovote, 1095.
Ray, Pinal Co.: Clifford, 206.
Miami copper district: Weed, 1174.
Miami copper mine, Globe: Loveman, 682.
Morenci-Metcalf district: Butler, 139.
Nitrate deposits: Gale, 348.
Owl Head district, Apache mines: Pickard, 856.
Silverbell district: Stewart, 1037, 1039.
Dynamic and structural.
Earthquake, 1912: Tolman, 1093.
Silica and lime deposition: Darton, 262.
Physiographic.
Grand Canyon district: Johnson, 552.
Meteor Crater (Coon Butte): Thomson, 1083.
Stratigraphic:
Grand Canyon: Darton, 263.
Paleontology.
Tertiary freshwater Mollusca: Hannibal, 427.
Mineralogy.
Holbrook meteorite: Merrill, 750.
Holbrook meteoric shower: Foote, 333.

Arkansas.
General.
Diamond-bearing peridotite area: Glenn, 374, 375.
Economic.
Coal: Steel, 1027.
Fuller's earth: Branner, 102.
Mineral resources: Purdue, 876.
Phosphates: Waggaman, 1141.
Semi-anthracite field, Sebastian Co.: Shaw, 969.
Arsenic.
United States: U. S. G. S., 1127.
Artesian waters and wells. *See* Underground water.
Arthropoda. *See also* Arachnida; Crustacea; Insecta.
New York. Eurypterida: Clarke, 198; Clarke and Ruedemann, 201.
Asaphidæ, parallelism: Raymond, 889.
Asbestos.
General: Springer, 1013.
Canada: Pearson and Hoff, 838.
Quebec: Denis, 278.
United States: U. S. G. S., 1127.
Vermont: Perkins, 846.
Asphalt. *See also* Asphaltite; Grahamite.
Trinidad: Richardson, 907.
United States: U. S. G. S., 1127.
Associations, meetings.
Geological Society America, Proceedings, twenty-fourth meeting: Hovey, 502, 503, 504.
Cordilleran section, proceedings, twelfth meeting: Louderback, 678.
Paleontological Society, third annual meeting: Bassler, 52.
Asteroidea.
Carboniferous, Montana: Raymond, 890.
Feeding habits: Clarke, 200.
New York, Devonian: Clarke, 198.
Onychaster, structure: Schöndorf, 952.
Ordovician, Ontario: Raymond, 890.
Protopalæaster narrawayi: Raymond, 891.
Starfish with ambulacral covering plates: Hudson, 519.
Aves.
Pacific coast: Miller, 762.
Baddeleyite from Montana: Rogers, 922.
Baker lignite field, Custer County, Montana: Bowen, 93.
Bannock overthrust, Idaho and Utah: Richards and Mansfield, 903.
Barbados.
General: Guppy, 413.
Barite. *See also* Barytes.
Tennessee: Henegar, 446.
Barytes. *See also Barite.*
Missouri: Wittich, 1235.
United States: U. S. G. S., 1127.
Basin-range structure: Burling, 134.
Bathurst district, New Brunswick: Young, 1258.
Bathyliths. *See* Intrusions.
Batrachia. *See* Amphibia.
Bauxite.
Tennessee: Ashley, 27, 28.
United States: U. S. G. S., 1127.
Beaches. *See also* Shore lines; Terraces.
Quebec, Covey Hill region: Spencer, 1010.
Beaverdell map area, Yale district, B. C.: Reinecke, 900.
Bibliography.
Abrasives: U. S. G. S., 1127.
Aluminum: U. S. G. S., 1127.
Artiodactyla: Peterson, 847.
Asphalt: U. S. G. S., 1127.
Avian faunas of Pacific coast: Miller, 762.
Bannock overthrust, Idaho-Utah: Richards and Mansfield, 903.
Barytes: U. S. G. S., 1127.
Bauxite: U. S. G. S., 1127.
Borax: U. S. G. S., 1127.
British Columbia, Vancouver Island: Clapp, 182.
Brush, G. J., writings: Dana, 258; Ford, 337.
Building stone: U. S. G. S., 1127.
Calvin, Samuel, writings: Shimek, 975.
Cambrian Brachiopoda: Walcott, 1150.
Cement: U. S. G. S., 1127.
Chelonia: Hay, 436.
Chert: Van Tuyl, 1138.
Clay: U. S. G. S., 1127.
Coal: U. S. G. S., 1127.
Coastal Plain, North Carolina: Clark *et al.*, 193.
Cobalt: U. S. G. S., 1127.
Coke: U. S. G. S., 1127.
Connecticut, Triassic: Lull, 688.
Cryolite: U. S. G. S., 1127.
Dan River Triassic coal field, North Carolina: Stone, 1046.
Earthquakes, New Madrid: Fuller, 343.
Echinoidea, American: Stefanini, 1028.
Economic geology, recent literature on: Knopf and Umpleby, 598–600; Loughlin and Goodspeed, 681; Umpleby, 1126.
Emmons, S. F., writings: Hague, 418, 419.
Eurypterida: Clarke and Ruedemann, 201.
Fluorspar: U. S. G. S., 1127.
Foraminifera, Tertiary and Pleistocene: Bagg, 35.
Fuller's earth: U. S. G. S., 1127.
Geodes: Van Tuyl, 1137.
Geology: Anon., 1274.
dynamic and structural, 1911: Woodworth, 1247.
Glass sand: U. S. G. S., 1127.
Graphite: Bastin, 55; U. S. G. S., 1127.
Pennsylvania: Miller, 759.
Hall, C. W., writings: Winchell, 1228.
Iron: U. S. G. S., 1127.
Lead: U. S. G. S., 1127.
Lime: U. S. G. S., 1127.

Bibliography—Continued.
Mammoth Cave: Hovey, 512.
Marble: Dale, 250.
Mica: U. S. G. S., 1127.
Mineral paints: U. S. G. S., 1127.
Mineralogy: Anon., 1274.
Molybdenum: U. S. G. S., 1127.
Monazite: U. S. G. S., 1127.
New Brunswick, Bathurst district: Young, 1258.
New Madrid earthquake: Fuller, 343.
New Mexico coal fields, stratigraphy: Lee, 648.
Nickel: U. S. G. S., 1127.
Niles, W. H., writings: Barton, 50.
North American geology, 1911: Nickles, 799.
North American stratigraphy: Willis, 1212.
Oregon: Henderson and Winstanley, 445.
Osborn, Henry Fairfield, writings: Ripley, 918.
Paleontology: Anon., 1274.
Peat: U. S. G. S., 1127.
Pennsylvania, graphite deposits: Miller, 759.
Permian reptiles: Case, 175.
Petroleum: Breger, 105; U. S. G. S., 1127.
Petrology: Anon., 1274.
Psygmophyllum: Arber, 20, 21.
Quicksilver: McCaskey, 693.
Salt: U. S. G. S., 1127.
Sand: U. S. G. S., 1127.
Sand-lime brick: Parr and Ernest, 831.
Tertiary, correlation and paleogeography: Osborn, 815.
Tin: Ferguson and Bateman, 322; U. S. G. S., 1127.
Titanium: U. S. G. S., 1127.
Tungsten: U. S. G. S., 1127.
Uranium: U. S. G. S., 1127.
Utah, Park City district: Boutwell, 92.
Vanadium: U. S. G. S., 1127.
Vancouver Island: Clapp, 182.
Vermont, Green Mountain region: Perkins, 845.
Virginia, Coastal Plain: Clark and Miller, 192.
West Indies: Guppy, 411.
Wisconsin, Lake Superior sandstones: Thwaites, 1085.
Zinc: U. S. G. S., 1127.
Zircon: U. S. G. S., 1127.
Bighorn basin, Wyoming: Sinclair and Granger, 985.
Biography.
Brush, George Jarvis: Dana, 258; Ford, 337.
Buckley, E. B.: Anon., 1264, 1265.
Calvin, Samuel: Shimek, 975.
Davis, William Morris: Huntington, 523.
Dutton, C. E.: Becker, 60.
Ells, R. W.: Bishop, 75.
Biography—Continued.
Emmons, Samuel Franklin: Hague, 418, 419.
Hall, Christopher Webber: Winchell, 1228.
Howell, Edwin E.: Gilbert, 364.
McGee, W. J.: Anon., 1266, 1267.
Tarr, Ralph Stockman: Williams, 1208; Anon., 1268.
White, David: Anon., 1269.
Birds. *See* Aves.
Bismuth.
Quebec, northwestern: Bancroft, 43.
United States: U. S. G. S., 1127.
Bivalves. *See* Pelecypoda.
Black Mountain coal district, Kentucky: Dilworth, 284.
Black sands.
California, Feather River: Sperry, 1012.
Blacktail (Tabby) Mountain coal field, Wasatch Co., Utah: Lupton, 690.
Blowing wells. *See* Underground water.
Bolson, development of: Meinzer, 744.
Bonnifield region, Alaska: Capps, 170.
Borax.
California, Ryan, Lila C. mine: Gale, 351.
United States: U. S. G. S., 1127.
Borings.
Canada: Ingall, 532.
Illinois, Carlinville field: Kay, 563.
Carlyle oil field: Shaw, 970.
Peoria quadrangle: Udden, 1117.
Oklahoma, Ponca City field: Ohern and Garrett, 803.
Tennessee, Memphis: Munn, 786.
Texas: Udden, 1120.
Wichita and Clay counties: Udden and Phillips, 1121.
Wyoming, Converse and Carbon counties: Jamison, 539.
Botany, fossil. *See* Paleobotany.
Boulder beds of Caney shales, Talihina, Oklahoma: Woodworth, 1249.
Boundary district, British Columbia: LeRoy, 655.
Brachiopoda.
British Columbia, Ordovician: Walcott, 1146.
Cambrian: Walcott, 1150.
Cincinnatian and Mohawkian: Foerste, 327.
Devonian, Ohio: Prosser, 872.
Mississippian, Ohio: Prosser, 872.
Spirifer mucronatus, mutations: Grabau and Reed, 391.
Tertiary, Washington: Weaver, 1169.
Brachyostracon: Brown, 118, 121.
Breathing wells. *See* Underground water.
British Columbia.
General.
Beaverdell area, Yale district: Reinecke, 900.
Comox and Suquash coal fields, Vancouver Island: Clapp, 184.

British Columbia—Continued.
General—Continued.
East Kootenay: Schofield, 953, 954.
Field area, Yoho Park: Allan, 9.
Franklin mining camp, West Kootenay: Drysdale, 289.
Fraser Canyon: Camsell, 162.
Siwash Creek area: Bateman, 57.
Lillooet mining division, Yale district: Camsell, 163.
Observatory Inlet: McConnell, 694.
Portland Canal district: McConnell, 696.
Salmon River district: McConnell, 695.
Shuswap lakes region: Daly, 254.
Skagit Valley, Yale district: Camsell, 164.
Skeena River district: Malloch, 715.
Snowslides in mining districts: Lakes, 620.
Tulameen district, diamonds: Camsell, 165.
West Kootenay, Franklin mining camp: Drysdale, 289.
Economic.
Bear River coal field: Galloway, 353.
Clay and shale deposits: Ries and Keele, 916.
Coal fields: Denis, 277.
Copper: Wilson, 1218.
Klehini Valley: Bryant, 125.
East Kootenay: Schofield, 953.
Fraser Canyon, Siwash Creek area: Bateman, 57.
Groundhog coal basin, Skeena district: Malloch, 714, 715.
Nelson area: LeRoy, 656.
Observatory Inlet, McConnell, 694.
Phoenix, Boundary district: LeRoy, 655.
Portland Canal district: McConnell, 696.
Report Bureau Mines, 1911: Robertson, 920.
Silver-lead deposits, East Kootenay: Schofield, 954.
Vancouver Island: Clapp, 182.
West Kootenay, Franklin mining camp: Drysdale, 289.
Physiographic.
Sir Sandford glacier, 1911: Palmer, 825.
Vancouver Island: Clapp, 182.
Stratigraphic.
Cambro-Ordovician boundary: Walcott, 1146.
Canada, Kicking Horse Valley: Walcott, 1152.
Field area, Yoho Park: Allan, 9.
Ice River district: Allan, 10.
Mount Bosworth: Burling, 135.
Nanaimo sheet, Vancouver Island: Clapp, 183.
Nelson area: LeRoy, 656.

British Columbia—Continued.
Stratigraphic—Continued.
Phoenix, Boundary district: LeRoy, 655.
Pre-Cambrian formations: Daly, 255, 256.
Sherbrooke formation: Burling, 135.
Shuswap lakes region: Daly, 254.
Skeena River region: Malloch, 715.
Vancouver Island: Clapp, 182.
geologic map: Clapp and Allan, 185.
West Kootenay, Franklin mining camp: Drysdale, 289.
Paleontology.
Cambrian fossils: Walcott, 1154.
Cambrian Branchiopoda: Walcott, 1145.
Olenopsis from Cambrian: Walcott, 1147.
Ordovician: Walcott, 1146.
Petrology.
Vancouver Island: Clapp, 182.
Bromine.
United States: U. S. G. S., 1127.
Bryozoa.
Indiana, Batostomas, Richmond series: Cumings and Galloway, 245.
Monticuliporoids, development and systematic position: Cumings, 243.
Building stone. *See also* Granite; Limestone; Sandstone; Stone.
General: Eckel, 304; Ries, 913.
Canada: Parks, 830.
maritime provinces: Parks, 829.
Granite, marbles, and other building stones of the South: Burchard, 130.
New York: Clarke, 198.
Quebec: Denis, 278.
Texas, Llano and Burnet quadrangles: Paige, 817.
United States: U. S. G. S., 1127.
east of Mississippi River: Burchard, 132.
Wisconsin, Lake Superior region: Thwaites, 1085.
Butte district, Montana: Weed, 1171.
Cadmium.
United States: U. S. G. S., 1127.
California.
General.
Amargosa Valley, nitrate prospects: Free, 340.
Report of State mineralogist: Aubury, 33; Cal. M. B., 156.
Searles Lake region: Hammon, 424, 425.
State Mining Bureau: Storms, 1055.
Economic.
Borax, Ryan: Gale, 351.
Feather River black sands: Sperry, 1012.
Harrison Gulch, Shasta Co.: Kramm, 607.

California—Continued.
Economic—Continued.
Helester mines, Placer Co.: Storms, 1054.
High Grade district: Stines, 1041, 1042; Storms, 1052.
Iron deposits, Eagle Mountains: Harder, 428.
√ Los Burros district: Davis, 268.
Mother Lode: Storms, 1053.
Nitrate deposits: Gale, 348.
Oil fields: Prutzman, 875; Requa, 901.
Potash, Searles Lake region: Hammon, 424, 425.
San Joaquin Valley: Anderson, 15.
Sierra Nevada mineral deposits: Storms, 1051.
Dynamic and structural.
√ Changes of level: Wittich, 1233.
Earthquakes, after-shocks: Kiess, 580.
of 1911, region of origin: Wood, 1241.
registration at Berkeley: Wood, 1238, 1239, 1240.
Pseudostratification, Santa Barbara Co.: Louderback, 677.
√ Silica and lime deposition: Darton, 262.
Physiographic.
El Paso Range and southern Sierra Nevada: Baker, 39.
Yosemite Valley: Matthes, 728.
Stratigraphic.
Eagle Mountains: Harder, 428.
El Paso Range and southern Sierra Nevada: Baker, 39.
Miocene of southern coast range region: Louderback, 679.
Monterey series: Martin, 718.
Neocene section at Kirker Pass: Clark, 188.
San Joaquin Valley: Anderson, 15.
Tertiary deposits near Coalinga oil field: Dumble, 293.
Triassic, Shasta Co. section: Smith, 995.
Tuolumne Table Mountain: Locke, 675.
Paleontology.
Miocene invertebrates: Smith, 996.
Monterey series, Martin, 718.
Pleistocene rodents: Kellogg, 569.
Pliocene and Pleistocene Foraminifera: Bagg, 35.
Rancho La Brea fauna, Canidæ: Merriam, 745.
Carnivora: Merriam, 746.
Tertiary freshwater Mollusca: Hannibal, 427.
Mineralogy.
Cuprodescloizite: Schaller, 936.
Manganese phosphates from gem tourmaline field: Schaller, 939.
Rare minerals: Rogers, 927, 928.
Tourmaline: Schaller, 944.
Underground water.
Owens Valley: Lee, 644.
Cambria coal field, Wyoming: Simmons, 980.
Cambrian.
Stratigraphy.
General: Walcott, 1145.
Group terms: Walcott, 1149.
British Columbia, Cambro-Ordovician boundary: Walcott, 1146.
East Kootenay: Schofield, 953.
Field area: Allan, 9.
Ice River district: Allan, 10.
Kicking Horse Valley: Walcott, 1152.
Mount Bosworth: Burling, 135.
Sherbrooke formation: Burling, 135.
Shuswap lakes region: Daly, 254.
California, southeastern: Hershey, 452.
Colorado, Alma district, Patton *et al.*, 834.
Georgia, northern: Maynard, 738.
Idaho, Cœur d'Alene region: Hershey, 452.
Iowa: Norton *et al.*, 800.
Missouri, Ozark region: Crane, 233.
Nevada, eastern: Hershey, 452.
New York: Hartnagel, 432; Walcott, 1148.
North America: Willis, 1212.
Nova Scotia, Arisaig-Antigonish district: Williams, 1211.
Pennsylvania, central: Ziegler, 1262.
Lehigh region: Miller, 757; Peck, 839.
South Mountain: Eaton, 303.
Quebec, Orford area: Harvie, 433.
southern: Dresser, 288.
Texas, Llano and Burnett quadrangles: Paige, 817.
Vermont, Albany terranes: Richardson and Collister, 905.
Craftsbury: Richardson, 904.
Green Mountain region: Perkins, 845.
Irasburg terranes: Richardson and Conway, 906.
West Virginia, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Wyoming, Douglas oil field, Converse Co.: Jamison, 539.
Paleontology.
General: Anonymous, 1275.
Alabama: Walcott, 1144.
Asaphidæ: Raymond, 889.
Brachiopoda: Walcott, 1150.
Branchiopoda, Malacostraca, Trilobita and Merostomata: Walcott, 1145.
British Columbia: Walcott, 1154.
Kicking Horse Valley: Walcott, 1152.
New York, Potsdam-Hoyt fauna: Walcott, 1148.
Olenopsis: Walcott, 1147.
Scotland and North America, faunas compared: Peach, 836.
Tennessee: Walcott, 1144.
Canada (general). *See also* names of provinces.
General.
Bore-hole records: Ingall, 532.

Canada—Continued.
General—Continued.
Geological Survey, Summary report: Brock, 107.
Report of Mines Branch: Canada, Mines Branch, 166.
Economic.
Asbestos: Pearson and Hoff, 838.
Building and ornamental stones: Parks, 830.
Clay and shale deposits, western provinces: Ries and Keele, 916.
Clay resources: Keele, 564, 565, 567; Ries, 914.
Coal fields: Denis, 277.
western Canada: Jacobs, 536.
Coal resources: Dowling, 287.
Gypsum and salt: Cole, 215.
Mica: Schmid, 949.
Mineral production, 1910: McLeish, 708.
Peat bogs: Anrep, 19.
Pyrites: Wilson, 1217, 1218.
Paleontology.
Report on invertebrates: Raymond. 888.
Report paleontological division: Lambe, 626.
paleobotany: Wilson, 1222.
Steeprock series fauna: Walcott, 1151.
Vertebrates: Lambe, 625.
Mineralogy.
Report mineralogical division: Johnston, 556.
Carboniferous.
Stratigraphy.
General: Stevenson, 1036.
Alabama, coal pebbles: Prouty, 874.
Fayette field: Munn, 785.
Alberta, Roche Miette area: Dowling, 285.
Alaska, Gulkana-Susitna region: Moffit, 769.
Porcupine to Arctic boundary: Maddren, 712.
Alaska-Yukon boundary: Cairnes, 150.
British Columbia, Boundary district: LeRoy, 655.
East Kootenay: Schofield, 953.
Fraser Canyon: Camsell, 162.
Nelson area: LeRoy, 656.
Skagit Valley, Yale district: Camsell, 164.
Shuswap lakes region: Daly, 254.
Vancouver Island: Clapp, 182.
Colorado, Alma district: Patton *et al.*, 834.
Grand Mesa and West Elk Mountains: Lee, 647.
Lykins formation: Girty, 368.
Georgia, northern: Maynard, 738.
Idaho, east: Umpleby, 1123.
southeastern: Richards and Mansfield, 903.
Illinois: Blatchley, 79.
Carlinville field: Kay, 563.
Carlyle oil fields: Shaw, 970.
Carboniferous—Continued.
Stratigraphy—Continued.
Illinois—Continued.
Mazon Creek: Moodie, 775.
Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Peoria quadrangle: Udden, 1117.
Iowa: Keyes, 578; Norton *et al.*, 800.
southeastern: Van Tuyl, 1136.
Kansas: Parker, 826.
Kentucky, Black Mountain district: Dilworth, 284.
Campton field: Munn, 783.
Chattanooga shale: Kindle, 582.
Chattanoogan series: Ulrich, 1122.
eastern: Miller, 756.
Hartford quadrangle: Gardner, 355.
Kenova quadrangle: Phalen, 850.
Kentucky River region: Hodge, 479.
Knox Co.: Munn, 784.
Pineville Gap: Crandall and Sullivan, 232.
Tradewater River region: Glenn, 371.
Webster Co.: Glenn, 372.
Maryland, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Missouri, Ozark region: Crane, 233.
Montana, Electric coal field: Calvert, 159.
Nebraska: Barbour, 45.
New Brunswick: Stopes, 1049.
Bathurst district: Young, 1258.
Moncton area: Young, 1259.
New Mexico, northern: Williston and Case, 1216.
New York: Hartnagel, 432.
North America: Willis, 1212.
Nova Scotia: Arisaig-Antigonish district: Williams, 1211.
Joggins section: Bell, 65.
Ohio, Bedford-Berea disconformity: Prosser, 871.
Chattanoogan series: Ulrich, 1122.
Cleveland shale, age: Cushing, 246.
Columbus quadrangle: Stauffer, *et al.*, 1025.
Fairfield, Co.: Hyde, 528.
Kenova quadrangle: Phalen, 850.
northeastern: Prosser, 872.
Oklahoma, northeastern: Snider, 1005.
Ponca City field: Ohern and Garrett, 803.
red beds: Beede, 62.
Osage series cherts: Van Tuyl, 1138.
Pennsylvania, Claysville quadrangle: Munn, 782.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Washington and Greene counties: Bolleau, 90.
Permian series: La Forge, 615.
Prince Edward Island: Watson, 1159.
Rhode Island, Narragansett Basin: Lahee, 617.

Carboniferous—Continued.
Stratigraphy—Continued.
Tennessee, Chattanoogan series: Ulrich, 1122.
Texas, Llano and Burnet quadrangles: Paige, 817.
Utah, northeastern: Richards and Mansfield, 903.
Park City district: Boutwell, 92.
San Juan oil field: Woodruff, 1243.
Virginia: Branson, 103.
West Virginia, Doddridge and Harrison counties: Hennen, 447.
Kenova quadrangles: Phalen, 850.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Wyoming, Douglas oil field, Converse Co.: Jamison, 539.
Yukon, Porcupine to Arctic boundary: Maddren, 712.
Paleontology.
Colorado, Lykins fauna: Girty, 368.
Diplocaulia, Texas: Moodie, 773.
Echini: Jackson, 535.
Fusulinidæ of North America: Staff, 1017.
Iowa, Edestus: Hay, 438.
Lepidostrobus, Warren Co., Iowa: Tilton, 1086.
Montana, starfish: Raymond, 890.
Naticopsis: Girty, 369.
Nebraska, Eurypterids: Barbour, 45.
Newfoundland, Psygmophyllum: Arber, 20, 21.
New Mexico, Limnoscelis: Williston, 1214.
Ohio, northeastern: Prosser, 872.
Texas, cockroaches: Cockerell, 212.
Utah, Park City district: Boutwell, 92.
West Virginia, Ames limestone fossils: Beede, 61.
Canal Zone. *See* Panama.
Caney shales, Oklahoma: Woodworth, 1249.
Carlyle oil field of Illinois: Shaw, 970.
Cartography.
Planetable in geologic mapping: Pelton and Irwin, 840; Ransome, 884; Wegemann, 1180.
Progress in 1910: Adams, 2.
Castle Dome lead district, Ariz.: Nevius, 797.
Caverns. *See* Caves.
Caves.
Kentucky, Colossal Cavern: Hovey, 511.
Mammoth Cave: Hovey, 510, 511; Turner, 1112.
bibliography: Hovey, 512.
Nova Scotia, Hants County: Prest, 867.
Tennessee, Monteagle Cave: Nelson, 796.
Cave marble.
Tennessee: Gordon, 380.
Cebolla district, Gunnison County: Singewald, 988.
Cement and cement materials.
Georgia, north: Maynard, 738.
Illinois: Bleininger *et al.*, 84.
Michigan: Allen *et al.*, 13.
New York: Newland, 798.
Oregon: Parks, 828.
Pennsylvania, Lehigh district: Peck, 839.
United States: U. S. G. S., 1127.
Central America. *See* Costa Rica; Guatemala, etc.
Cephalopoda. *See also* Mollusca.
Jurassic and Cretaceous, Mexico: Burckhardt, 133.
Plectoceras jason, New York: Ruedemann, 933.
Cetacea.
Correlation North American and European genera: True, 1108.
Whalebone whales allied to Balænoptera: True, 1106.
Ceratopsia, evolution: Lull, 686.
Changes of level. *See also* Beaches; Shore lines; Terraces.
General: Hull, 522.
Alaska, Yakutat Bay: Tarr and Martin, 1066.
Atlantic coast: Johnson, 550, 551.
California: Wittich, 1233.
Massachusetts: Davis, 266, 267.
Mexico, Lower California: Wittich, 1233.
New Brünswick, postglacial: Goldthwait, 378.
Quebec, postglacial: Goldthwait, 378.
Chattanoogan series: Ulrich, 1122.
Chemical analyses. *See list, p. 165.*
Chert. *See* Flint.
Cherts of Osage series, origin: Van Tuyl, 1138.
Chromium.
General: Watson, 1163.
Quebec: Denis, 278.
Chimæroids, Cretaceous: Hussakof, 526.
Chontales mining district, Nicaragua: Feust, 324.
Choptank quadrangle, Maryland: Miller, 758.
Classification.
Copper: Butler, 140.
Echini: Jackson, 535.
Igneous rocks: Johnson and Tibby, 553.
symbols in quantitative classification: Cross, 239.
Meteorites: Foote Min. Co., 334.
Ore deposits: Weed, 1175.
Permian: La Forge, 615.
Quantitative classification, modifications of: Cross *et al.*, 240.
Clay. *See also* Fire clay.
General: Eckel, 304; Ries, 913.
Geology and mining: Soper, 1006.
Canada: Keele, 564, 565, 567; Ries, 914.
western provinces: Ries and Keele, 916.

Clay—Continued.
Georgia, north: Maynard, 738.
Illinois, Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Kentucky, Hartford quadrangle: Gardner, 355.
Kenova quadrangle: Phalen, 850.
New York: Newland, 798.
Ontario: Ries, 915.
Oregon: Parks, 828.
Quebec: Ries, 915.
South, deposits in: Middleton, 755.
Tennessee, Henry Co.: Kirkpatrick and Nelson, 587.
United States: U. S. G. S., 1127.
Virginia, Coastal Plain: Watson, 1161.
West Virginia, Doddridge and Harrison counties: Hennen, 447.
Climate, geologic. *See* Paleoclimatology.
Clymenia fauna in American Devonian: Raymond, 887.
Coal. *See also* Anthracite; Lignite.
General: Stoek, 1043.
Accumulation, Perry Co., Ohio: Hyde, 529.
Analyses: U. S. G. S., 1128.
Formation of coal beds: Stevenson, 1036.
Genesis: Thiessen, 1075.
Resins in Paleozoic coals: White, 1196.
Alaska, Bonnifield region: Capps, 170.
Matanuska Valley: Martin and Katz, 722.
Alberta: Denis, 277; Dowling, 286. Fullerton, 347.
Blairmore area: Leach, 643.
Roche Miette area: Dowling, 285.
Arkansas: Steel, 1027.
Sebastian Co.: Shaw, 969.
Black Hills region: Stone, 1045.
British Columbia: Denis, 277.
Bear River field: Galloway, 353.
Comox and Suquash fields: Clapp, 184.
Groundhog basin, Skeena district Malloch, 714, 715.
Vancouver Island: Clapp, 182.
Canada: Denis, 277; Dowling, 287.
western: Jacobs, 536.
Colorado, central: Whiteside, 1198.
Gunnison Valley: Woodruff, 1245.
lignite fields: Pierce, 857.
Trinidad district: Whiteside, 1197.
Illinois, Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Peoria quadrangle: Udden, 1117.
Kentucky, Black Mountain district: Dilworth, 284.
Cumberland field: Hodge, 480.
eastern field: Miller, 756.
Hartford quadrangle: Gardner, 355.
Kenova quadrangle: Phalen, 850.

Coal—Continued.
Kentucky—Continued.
Kentucky River, three forks: Hodge, 479.
Licking Valley region: Crandall, 231.
Pineville Gap: Crandall and Sullivan, 232.
Quicksand creeks region: Fohs, 330.
Tradewater River region: Glenn, 371.
Webster Co.: Glenn, 372.
Maryland, Georges Creek field: Hall, 423.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Michigan: Allen *et al.*, 13.
Montana, Baker field, Custer Co.: Bowen, 93.
Culbertson field: Beekly, 63.
Electric field, Park Co.: Calvert, 159.
Glendive lignite field, Dawson Co.: Hance, 426.
Livingston and Trail Creek fields: Calvert, 158.
Milk River field: Pepperberg, 842.
Sidney field, Dawson Co.: Stebinger, 1026.
Terry field, Custer Co.: Herald, 448.
New Brunswick: Denis, 277.
New Mexico, northern central: Lee, 648.
Tijeras field, Bernalillo Co.: Lee, 646.
North Carolina, Dan River field: Stone, 1046.
North Dakota, Fort Berthold Indian Reservation: Pishel, 861.
Nova Scotia: Denis, 277.
Ohio, Kenova quadrangle: Phalen, 850.
Oregon: Parks, 828.
Panama: MacDonald, 699.
Pennsylvania, Claysville quadrangle: Munn, 782.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Washington and Greene counties: Boileau, 90.
Saskatchewan: Denis, 277; Dowling, 286.
United States: Guillotel, 407; U. S. G. S., 1127.
Utah, Blacktail Mountain field, Wasatch Co.: Lupton, 690.
Uinta Co., Vernal field: Lupton, 689.
Washington, King County: Evans, 313.
Roslyn field: Daniels, 259.
West Virginia, Doddridge and Harrison counties: Hennen, 447.
Kenova quadrangle: Phalen, 850.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
southern: Parsons, 833.

Coal—Continued.
Wyoming, Cambria coal field: Simmons, 980.
Little Powder River field, Campbell Co.: Davis, 269.
Lost Spring field: Winchester, 1231.
Sheridan coal field: Simmons, 981.
Sussex field: Wegemann, 1179.
Wind River region: Woodruff and Winchester, 1246.
Yukon: Denis, 277.
Wheaton district: Cairnes, 149.
Coal Measures. *See* Carboniferous.
Coast lines.
Mexico, Lower California: Wittich, 1232.
Coastal Plain: Crosby, 235.
Cobalt.
United States: U. S. G. S., 1127.
Cobalt, Ontario: Tyrrell, 1115.
Cochita mining district, New Mexico: Statz, 1021.
Coelenterata. *See* Anthozoa; Hydrozoa.
Coke.
United States: U. S. G. S., 1127.
Colorado.
Economic.
Alma district, Park Co.: Patton *et al.*, 834.
Alunite deposits of Rosita Hills: Cross, 236.
Apishapa quadrangle: Stose, 1056.
Breckenridge placers: Lakes, 619.
Cebolla district, Gunnison Co.: Singewald, 988.
Central coal fields: Whiteside, 1198.
Coal fields of Grand Mesa and West Elk Mountains: Lee, 647.
Gold of Newlin's Gulch: Butler, 147.
Gunnison Valley, coal resources: Woodruff, 1245.
Iron, titaniferous, Boulder County: Jennings, 544.
Leadville: Butler, 144, 145; Moore, 777.
Lignite fields: Pierce, 857.
Nitrate deposits: Gale, 348.
Placer mines of Summit County: Brown, 122.
Trinidad district: Whiteside, 1197.
Tungsten deposits, Boulder Co.: Greenawalt, 396.
Vanadium, southwestern Colorado: Thomas, 1078.
Dynamic and structural.
Glacial erosion, San Juan Mountains: Hopkins, 492.
Sandstone pinnacles: Darton, 261.
Physiographic.
Apishapa quadrangle: Stose, 1056.
Mesa Verde: Atwood, 30.
San Juan Mountains: Atwood and Mather, 32; Hopkins, 492.
Telluride quadrangle, glaciation: Hole, 485.
Colorado—Continued.
Stratigraphic.
Alma district, Park Co.: Patton *et al.*, 834.
Apishapa quadrangle: Stose, 1056.
Front Range, foothills, structure: Richardson, 910.
Glacial epochs in San Juan Mountains: Atwood and Mather, 32.
Grand Mesa and West Elk Mountains: Lee, 647.
Gunnison Valley, coal resources: Woodruff, 1245.
Monument Creek group: Richardson, 908.
San Juan Mountains, glacial epochs: Atwood and Mather, 32.
Telluride quadrangle, glaciation: Hole, 485.
Paleontology.
Animasaurus carinatus: Case and Williston, 177.
Florissant: Cockerell, 208.
Coleoptera: Wickham, 1202, 1203.
Odonata: Ris, 919.
Raphidia: Cockerell, 211.
Trichocnemis: Muttkowski, 789.
Fruits and flowers: Cockerell, 209.
Lykins fauna: Girty, 368.
Petropteron, Pierre formation: Cockerell, 210.
Tertiary freshwater Mollusca: Hannibal, 427.
Tertiary fungus gnat: Johannsen, 548.
Petrology.
Apishapa quadrangle: Cross, 237; Stose, 1056.
Mineralogy.
Calamine, Leadville: Paul, 835.
Hinsdalite: Larsen and Schaller, 634.
Hinsdalite and natramblygonite: Schaller, 936.
Pyrite crystals, Spanish Peaks: Zimányi, 1263.
Coloration in fossils: Girty, 369.
Colossal Cavern: Hovey, 511.
Columbus quadrangle, Ohio: Stauffer *et al.*, 1025.
Comstock, vein systems: Smith, 991.
Concretions.
Siliceous oolites: Moore, 778.
Texas: Udden and Phillips, 1121.
Congresses. *See* Associations.
Connecticut.
General.
Report of geological survey: Conn. G. S., 221.
Physiographic.
Connecticut Valley: Lull, 688.
Stratigraphic.
General: Cleland, 202, 203.
Central Connecticut: Barrell, 47.
Connecticut Valley: Lull, 688.
Preston region: Loughlin, 680.
Paleontology.
Connecticut Valley: Lull, 688.

Connecticut—Continued.
Petrology.
Gabbros and associated rocks at Preston: Loughlin, 680.
Mineralogy.
Tourmaline: Schaller, 944.
Contact mining district, Elko Co., Nev.: Schrader, 955.
Contact phenomena.
Arizona, Silverbell district: Stewart, 1037.
Mexico, San Luis Potosi, Dolores deposit: Spurr *et al.*, 1016.
Continental platform: Hull, 522.
Copper.
General.
Geologic classification: Butler, 140.
Gossan outcrops of cupriferous pyrite: Turner, 1111.
Secondary enrichment: Welsh and Stewart, 1181.
Alaska, Chitina district: Moffit, 771.
Iliamna region: Martin and Katz 721.
Taral district: Moffit, 770.
Arizona, Copper Butte: Probert, 870.
Globe, Miami mine: Loveman, 682.
Miami district: Weed, 1174.
Morenci-Metcalf district: Butler, 139.
porphyry deposits: Tovote, 1095.
Silverbell district: Stewart, 1037, 1039.
British Columbia: Wilson, 1218.
Boundary district, Phoenix: LeRoy, 655.
Klehini Valley: Bryant, 125.
Nelson area: LeRoy, 656.
Vancouver Island: Clapp, 182.
Lake Superior copper formation: Hubbard, 516, 517; Sperr, 1011.
Mexico, Sierra Mojada district: Van Horn, 1135.
Sonora, Elisa mine: Lee, 645.
Sahuaripa district: Hynes, 530.
Michigan: Allen *et al.*, 13; Hore, 495; Hubbard, 516, 517.
Keweenaw series: Lane, 627, 629.
Lake Superior region: Meuche, 752; Rice, 902.
Montana, Blue Bird mine: Winchell and Winchell, 1227.
Butte district: Kirk, 586; Weed, 1171.
Nevada, Contact district, Elko Co.: Schrader, 955.
Ely district: Weed, 1176.
Lyon Co., Nevada-Douglas mines: Read, 892.
New Mexico, Hell Canyon district: Statz, 1020.
Ray, Pinal Co.: Clifford, 206.
Santa Rita, Grant Co.: Clifford, 205.
Ontario, Point Mamainse: Lane, 628.
Sudbury field: Coleman, 216; Hore, 496.

Copper—Continued.
Quebec: Denis, 278.
United States: Guillotel, 407; U.S. G.S., 1127.
Washington, Index district: Weaver, 1168.
Coral reefs and islands.
Devonian, New York: Smith, 990.
Formation: Howe, 515.
Reef-building and land-forming seaweeds: Howe, 514.
Coral reefs in Triassic: Smith, 995.
Corals. *See* Anthozoa.
Correlation. *See* Stratigraphic.
Costa Rica.
Dynamic and structural.
Earthquakes, 1888: Michaud, 754.
1900: Tristán, 1100.
1910–1911: Tristán, 1099.
1911: Tristán and Biolley, 1102.
1912: Tristán, 1097.
Guatuso, 1911: Tristán, 1098.
Sarchi: Tristán *et al.*, 1103.
Toro Amarillo: Alfaro *et al.*, 8.
Earthquakes and volcanic eruptions: Tristán, 1096.
Volcano Reventado: Tristán, 1101.
Physiographic.
General: Pittier, 862.
Stratigraphic.
General: Romanes, 931.
Peninsula of Nicoya: Romanes, 932.
Paleontology.
New species of fossil shells: Dall, 253.
Craftsbury terranes, Vermont: Richardson, 904.
Craniometry of Equidæ: Osborn, 813.
Crescentic fractures of glacial origin: Lahee, 616.
Cretaceous.
Stratigraphy.
Alaska: Martin, 720.
Matanuska Valley: Martin and Katz, 722.
Orange group: Cairnes, 154.
Alaska-Yukon boundary: Cairnes, 150.
Alberta, Blairmore area: Leach, 643.
Roche Miette area: Dowling, 285.
British Columbia, Fraser Canyon: Camsell, 162.
Skagit Valley, Yale district: Camsell, 164.
Skeena River region: Malloch, 715.
Vancouver Island: Clapp, 182.
Nanaimo sheet: Clapp, 183.
California, Coalinga oil field region: Dumble, 293.
Canada, western: Ries and Keele, 916.
Colorado, Apishapa quadrangle: Stose, 1056.
Grand Mesa and West Elk Mountains: Lee, 647.
Greenland, northeast: Ravn, 886.
western: Heim, 443.
Iowa: Norton *et al.*, 800.

Cretaceous—Continued.
Stratigraphy—Continued.
Kansas: Parker, 826.
Mexico, Durango, San Pedro del Gallo: Burckhardt, 133.
eastern: Dumble, 294.
Montana, Culbertson field, Valley Co.: Beekly, 63.
Custer Co., Terry lignite field: Herald, 448.
Electric coal field: Calvert, 159.
eastern: Calvert, 157.
Livingston and Trail Creek fields: Calvert, 158.
Milk River field: Pepperberg, 842.
Nevada, Elko Co.: Schrader, 955.
New Mexico, north central: Lee, 648.
North America: Willis, 1212.
North Carolina, Coastal Plain: Clark *et al.*, 193.
North Dakota, Bismarck quadrangle: Leonard, 654.
South Dakota, Black Hills: Stone, 1045.
south central: Perisho and Visher, 843.
Texas, Llano and Burnet quadrangles: Paige, 817.
Utah, Uinta Co., Deep Creek district: Lupton, 689.
Virginia, Coastal Plain: Berry, 67; Clark and Miller, 192.
Wyoming, Black Hills: Stone, 1045.
Douglas oil field, Converse Co.: Jamison, 539.
Muddy Creek oil field, Carbon Co.: Jamison, 539.
Powder River oil field: Wegeman, 1178.
Salt Creek oil field, Natrona Co.: Jamison, 540.
Sussex coal field: Wegemann, 1179.
Wind River region: Woodruff and Winchester, 1246.
Yukon, Orange group: Cairnes, 154.
Wheaton district: Cairnes, 149.
Paleontology.
Alberta, Cretaceous dinosaur: Brown, 120.
Ceratopsia, evolution: Lull, 686.
Chimæroids: Hussakof, 526.
Colorado, fossil fruits and flowers: Cockerell, 209.
Pierre formation, insect: Cockerell, 210.
Conifers, structure: Thompson, 1082.
Dinosauria: Lull, 687.
Greenland, northeast: Ravn, 886.
Mexico, San Pedro del Gallo: Burckhardt, 133.
Mosasauroid reptile from Alabama: Gilmore, 365.
New Jersey, palm: Stevens, 1035.
Pityoxylon: Bailey, 37.
Pleurotomidæ: Pilsbry, 860.
New Mexico, distribution: Lee, 648.

Cretaceous—Continued.
Paleontology—Continued.
New York, Long Island, Cretaceous: Hollick, 489.
North Carolina, Coastal Plain: Clark *et al.*, 193.
Texas, Mesozoic flora: Berry, 70.
Virginia, Coastal Plain: Clark and Miller, 192.
Crinoidea. *See also* Echinodermata.
Devonian, Montana: Raymond, 890.
New York, Devonian: Olsson, 805.
Cripple Creek gold area: Bruce, 124.
Crustacea.
British Columbia, Cambrian: Walcott, 1145.
Cryolite.
United States: U. S. G. S., 1127.
Cryptogams. *See* Paleobotany.
Crystallization, order in igneous rocks: Bowen, 96.
Crystallography.
General.
Color scheme for crystal models: Chadwick, 178.
Crystallographic tables: Bowles, 101; Wherry, 1186; Whitlock, 1200.
Heat conductivity of crystals: Clark, 194.
Britholite: Bøggild, 85.
Calamine, Mexico: Seebach and Paul, 959.
Chrysoberyl and pyroxene: Whitlock, 1199.
Cryolite group: Bøggild, 86.
Cryolite, perovskite, and boracite, Bøggild, 85.
Gypsum: Kraus and Youngs, 609.
Herderite from Maine: Ford, 336.
Lead silicates: Kraus *et al.*, 610.
Mineral sulphides of iron: Larsen, 633.
Mosesite: Schaller, 936.
Pyrite: Zimanyi, 1263.
Quartz, Alexander Co., North Carolina: Pogue and Goldschmidt, 864.
Turquoise, Virginia: Schaller, 936, 938.
Variscite, Utah: Schaller, 936, 940, 941.
Cuba. *See also* West Indies.
Economic.
Iron deposits, Mayari: Guardiola, 406.
Culbertson lignite field, Valley County, Montana: Beekly, 63.
Cuyuna iron range, Minnesota: Thomas, 1079.
Cycadeoidea, flower buds: Wieland, 1204.
Daemonelix: Perisho and Visher, 843.
Dan River coal field, North Carolina: Stone, 1046.
Decomposition of rocks. *See* Weathering.
Deep Creek district, Uinta Co., Utah: Lupton, 689.
Definitions. *See* Nomenclature.
Delphinodon from Miocene of Maryland: True, 1105.

Deltas.
Ancient delta deposits: Grabau, 389.
Criteria for recognition of delta deposits: Barrell, 48.
Delta deposits: Barrell, 48; Grabau, 389.
Esker fans, structure: Jaggar, 537.
Virginia, New River district, Mississippian delta: Branson, 103.
Deposition. *See also* Sedimentation.
Silica and lime deposition: Darton, 262.
Deposition of ores. *See* Ore deposits, origin.
Deserts.
North American deserts: Macdougal, 703.
Devonian.
General.
Climatic zones: Matthew, 730.
Stratigraphy.
Alaska, Porcupine to Arctic boundary: Maddren, 712.
Alberta, Roche Miette area: Dowling, 285.
Greenland, Julianehaab region: Ussing, 1130.
Georgia, northern: Maynard, 738.
Idaho, east: Umpleby, 1123.
Illinois, Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Peoria quadrangle: Udden, 1117.
Iowa: Keyes, 578; Norton *et al.*, 800.
Cedar Valley-Lime Creek unconformity: Thomas, 1076.
Kentucky, Chattanooga shale: Kindle, 582.
Chattanoogan series: Ulrich, 1122.
Maryland, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Missouri, Ozark region: Crane, 233.
New Brunswick, Bathurst district: Young, 1258.
southern: Ells, 307.
New York: Clarke, 198; Hartnagel, 432.
Hamilton shale, coral beds: Smith, 990.
North America: Willis, 1212.
Nova Scotia, Arisaig-Antigonish district: Williams, 1211.
Ohio, Bedford shale: Girty, 370.
Chattanoogan series: Ulrich, 1122.
Cleveland shale, age: Cushing, 246.
Columbus quadrangle: Stauffer *et al.*, 1025.
Fairfield Co.: Hyde, 528.
northeastern: Prosser, 872.
northern: Kindle, 583.
Oklahoma, northeastern: Snider, 1005.
Onondaga formation, Allegheny region: Kindle, 581.
Ontario, Detroit River area: Nattress, 798.
Devonian—Continued.
Stratigraphy—Continued.
Ontario—Continued.
Oriskany sandstone: Stauffer, 1024.
southwestern: Stauffer, 1023.
Pennsylvania, Claysville quadrangle: Munn, 782.
Lehigh Gap: Miller, 757.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Quebec, Orford area: Harvie, 433.
Tennessee, Chattanoogan series: Ulrich, 1122.
Vermont, Craftsbury: Richardson, 904.
West Virginia, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Yukon, Porcupine to Arctic boundary: Maddren, 712.
Paleontology.
Clymenia fauna, Montana and New York: Raymond, 887.
Fishes from Scaumenac Bay, Quebec: Hussakof, 525.
Montana, crinoid: Raymond, 890.
New Brunswick, southern: Ells, 307.
New York: Clarke, 198; Olsson, 805.
Palæechinoidea: Olsson, 804.
starfishes near Saugerties: Clarke, 200.
Ohio, northeastern: Prosser, 872.
Onondaga fauna, Allegheny region: Kindle, 581.
Quebec, fishes from Scaumenac Bay: Hussakof, 525.
Diamonds.
General.
Genesis: Derby, 279.
Arkansas: Glenn, 374, 375.
British Columbia, Tulameen district: Camsell, 165.
Diatomaceous earth.
Virginia, Coastal Plain: Watson, 1161.
Diceratherium: Peterson, 849.
Dictyonema fauna of Navy Island, New Brunswick: Hahn, 421.
Differential erosion and equiplanation: Cairnes, 153.
Dikes.
Kentucky, Elliott dike: Crandall, 231.
Pennsylvania, South Mountain: Eaton, 303.
Dinosauria.
Alberta: Matthew, 733.
Ceratopsia, evolution: Lull, 686.
Crested dinosaur from Alberta: Brown, 120.
Cretaceous dinosaurs: Lull, 687.
Jurassic: Holland, 487.
Stegosaurus: Gilmore, 367.
Trachodon, integument: Osborn, 812.
Trachodontidæ, osteology of manus: Brown, 119.
Turtle, analogy to: Wieland, 1205.
Tyrannosaurus and Allosaurus: Osborn, 811.

Diplocaulia: Moodie, 773.
Dislocations. *See* Faulting.
Distribution. *See* Geographic distribution.
Dome theories in Gulf coast geology: Harris, 430.
Dome theory of the Coastal Plain: Lucas, 685.
Douglas oil field, Converse Co., Wyo.: Jamison, 539.
Drainage changes.
Nebraska, northeastern: Todd, 1088.
Ohio, Fairfield Co.: Hyde, 528.
Miami and Kentucky rivers: Fenneman, 320.
South Dakota, southeastern: Todd, 1088.
Drift deposits. *See also* Glacial geology.
Illinois, Wheaton quadrangle: Trowbridge, 1104.
Dunes.
Indiana: Shannon, 967.
Dynamic and structural (general). *For regional see names of States. See also list of subject headings on p. 114.*
Erosion observations, Clifty and Butler ravines, Jefferson Co.: Culbertson, 241.
Limestone, formation near tide level: White, 1195.
Pebble deposits: Bagg, 36.
Pseudostratification, Santa Barbara Co., Cal.: Louderback, 677.
Pyrite oxidation producing heated strata: MacDonald, 697, 698; Williams, 1208.
Reef-building and land-forming seaweeds: Howe, 514.
Ripple marks, tracks, and trails: Brown, 116.
Vein systems, relative age: Bustamante, 138.
Earth, interior.
Rocks, limiting strength: King, 585.
Zone of flow, depth: Adams, 3.
Earth, origin.
Radioactivity, bearings on geology: Chamberlin, 179.
Earth, temperature.
Geothermic gradients and petroleum: Shaw, 971.
Oil regions, temperature: Höfer, 482.
Radioactivity, bearings on geology: Chamberlin, 179.
Earth flow, Gros Ventre slide: Blackwelder, 78.
Earthquakes. *See also* Seismology.
General.
In 1911: Reid, 894.
Alaska, Yakutat Bay: Tarr and Martin, 1066.
Arizona, 1912: Tolman, 1093.
California: Wood, 1238–1241.
after-shocks: Kiess, 580.
Costa Rica: Tristán, 1096.
1888: Michaud, 754.
1900: Tristán, 1100.
Earthquakes—Continued.
Costa Rica—Continued.
1910–1911: Tristán, 1099.
1911: Tristán, 1098; Tristán and Biolley, 1102.
1912: Tristán, 1097.
Sarchi: Tristán *et al.*, 1103.
Toro Amarillo: Alfaro *et al.*, 8.
Haiti: Scherer, 947, 948.
Jamaica, earthquake of 1907: Cornish, 226.
Mexico, Guadalajara: Ordoñez, 807.
microseisms in 1911: Mexico G. S., 753.
Missouri, New Madrid: Fuller, 343.
New York, earthquakes registered at Albany: Clarke, 198.
United States and dependencies: Reid, 895.
East Kootenay, British Columbia: Schofield, 953, 954.
Eastport quadrangle, Maine, Paleozoic faunas: Williams, 1209.
Echini, phylogeny (Jackson): Schuchert, 956.
Echinodermata. *See also* Asteroidea; Blastoidea; Crinoidea; Cystoidea; Echinoidea.
Ordovician, Ontario: Raymond, 890.
Echinoidea.
Jackson on phylogeny of Echini: Schuchert, 956.
New York, Devonian: Olsson, 804.
Phylogeny of the Echini: Jackson, 535; Schuchert, 956.
Tertiary Echini: Stefanini, 1028.
Economic (general). *For regional see names of States. See also* Ore deposits, origin; *and the particular products.*
General: Stewart, 1038.
Applied geology: Brooks, 110.
Classification of metalliferous mineral lands: Stone, 1047.
Cross-fractures and ore shoots: Webber, 1170.
Examination of prospects: Gunther, 408.
Fissure veins, depth and continuity: Lakes, 623.
Fissures, depth of: Adams, 3.
Geological diagnosis: Irving, 534.
Geology and ore deposits: Weed, 1177.
Geology applied to mine examination: Joralemon, 561.
Hydrothermal alteration of granite: Moore, 779.
Literature, recent: Knopf and Umpleby, 598–600; Loughlin and Goodspeed, 681; Umpleby, 1126.
Oxidation of sulphides: Gottschalk and Buehler, 384.
Progress in 1911: Ransome, 883.
Replacement ore bodies: Stevens, 1031.
Shearage zones and mineral veins: Lakes, 622.

Economic (general)—Continued.
Teaching of economic geology: Smith, 1002; Tolman 1091.
Transportation and deposition of gold in nature: Lenher, 653.
Eczeme as geologic chronometer: Lachmann, 614.
Edentates, ancestry: Matthew, 734.
Educational. *See also* Textbooks.
Teaching of economic geology: Smith, 1002; Tolman, 1091.
Electric coal field, Park County, Montana: Calvert, 159.
Elevation and subsidence. *See* Changes of level.
Elk Mountain mining district, Elko Co., Nev.: Schrader, 955.
Ely district, Nevada: Weed, 1176.
Emanations.
Classification: Stevens, 1032.
Physical data: Stevens, 1033.
Emerald.
North Carolina: Sterrett, 1030.
Eocene. *See* Tertiary.
Eolation. *See* Wind work.
Eolian action. *See* Wind work.
Eozoon: Kirkpatrick, 588, 589.
Eozoon canadense, Cote St. Pierre, Quebec: Stansfield, 1018.
Equidæ, craniometry: Osborn, 813.
Equiplanation in Yukon and Alaska: Cairnes, 153.
Erosion. *See also* Glacial erosion; Sedimentation.
General: Tyrrell, 1116.
Arid regions: Keyes, 579.
Colorado, San Juan Mountains: Hopkins, 492.
Cross cutting and retrograding of stream beds: Dellenbaugh, 276.
Differential erosion and equiplanation: Cairnes, 153.
Indiana, Clifty and Butler ravines, Jefferson Co.: Culbertson, 241.
Niagara Gorge: Spencer, 1008.
Ohio, Plum Creek: Wright, 1256.
Peneplanation by wind: Keyes, 573.
Plateau plains: Keyes, 524.
Postglacial: Wright, 1256.
Rock-cut surfaces in desert ranges. Paige, 819.
Sandstone pinnacles: Darton, 261.
Eruptive rocks. *See* Igneous and volcanic rocks.
Esker fans, structure: Jaggar, 537.
Eskers.
Formation of: Trowbridge, 1104.
Essays. *See* Addresses.
Eurypterida: Clarke, 198; Clarke and Ruedemann, 201.
Evolution.
Limbs, origin from fins: Gregory, 401, 402, 403.
Origin of certain unit characters: Osborn, 810.
Paleontologist's view: Osborn, 808.
Tetraplasy: Osborn, 814.
Vertebrates: Williston, 1213.
Experimental investigations.
Flow of rocks: Adams, 3.
Ice, properties: Tarr and Rich, 1068.
Intrusions, effects: Garfias, 357.
Joint planes: Sheldon, 974.
Fanglomerate: Lawson, 639.
Faulting.
General: Lakes, 621.
Nomenclature: Reid, 897.
Alaska, Yakutat Bay: Tarr and Martin, 1066.
Colorado, Front Range: Richardson, 910.
Idaho, Bannock overthrust: Richards and Mansfield, 903.
Montana, Butte district: Weed, 1171.
Nevada, Genoa: Lawson, 638.
New York, overthrust faulting: Clarke, 198.
Utah, Bannock overthrust: Richards and Mansfield, 903.
Park City district: Boutwell, 92.
Feldspar.
New York: Newland, 798.
Ontario: Schmid, 950.
Quebec: Schmid, 950.
United States: U. S. G. S., 1127.
Field work.
Planetable in geologic mapping: Pelton and Irwin, 840; Ransome, 884; Wegemann, 1180.
Recording notes: Kümmel, 611.
Fire clay.
Colorado, Apishapa quadrangle: Stose, 1056.
Fishes. *See* Pisces.
Fissures. *See* Faulting.
Florida.
General.
Report Geological Survey, 1910–1911: Sellards, 960.
Road materials: Sellards *et al.*, 964.
Economic.
Phosphate, 1910: Sellards, 962.
Soils: Sellards, 961.
Underground water.
Western Florida: Sellards and Gunter, 963.
Fluorite.
Texas, Llano and Burnet quadrangles: Paige, 817.
Fluorspar.
United States: U. S. G. S., 1127.
Folding.
General: Lahee, 617.
Connecticut, Preston region: Loughlin, 680.
Footprints.
Connecticut, Triassic: Lull, 688.
Foraminifera.
California, Pliocene and Pleistocene: Bagg, 35.
Fusulinidæ: Staff, 1017.
Fossils. *See* Paleontology.
Fraser Canyon, British Columbia: Camsell, 162.

Fuller's earth.
General: Van Horn, 1134.
Arkansas: Branner, 102.
United States: U. S. G. S., 1127.
Fusulinidæ: Staff, 1017.
Garnet.
New York: Newland, 798.
Warren Co.: Miller, 764.
Gas. *See* Natural gas.
Gastroliths.
Stomach stones of reptiles: Moodie, 774.
Gastropoda. *See also* Mollusca.
Colorado: Lykins fauna: Girty, 368.
Naticopsis: Girty, 369.
New Jersey, Cretaceous, Pleurotomiidæ: Pilsbry, 860.
Protoconch in classification: Grabau, 387.
Tertiary Mollusca from the West: Cockerell and Henderson, 213.
Gems. *See* Precious stones.
Genesis of ores. *See* Ore deposits, origin.
Geochemistry.
Geochemical statistics: Clarke, 195.
Mineral sulphides of iron: Allen *et al.*, 12.
Oxidation of sulphides: Gottschalk and Buehler, 384.
Silica, forms and relations: Fenner, 321.
Temperature measurements of geological occurrences: Koenigsberger, 605.
Transportation and deposition of gold in nature: Lenher, 653.
Vanadium and chromium: Watson, 1163.
Geodes.
Origin: Van Tuyl, 1137.
Geographic distribution.
General: Scharff, 946.
Climate and evolution: Matthew, 735.
Eocene Mollusca: Maury, 736, 737.
Pleistocene faunas: Hay, 437.
Triassic, lower: Smith, 994.
Geologic climate. *See* Paleoclimatology.
Geologic formations described. *See list, p. 171.*
Geologic formations, tables. *See* Stratigraphic, Tables of formations.
Geologic history. *See also* Paleoclimatology; Paleogeography.
General.
Delta deposits: Barrell, 48.
Alaska, Gulkana-Susitna region: Moffit, 769.
Iliamna region: Martin and Katz, 721.
Koyukuk-Kobuk region: Smith, 1001.
California, Eagle Mountains: Harder, 428.
southern: Baker, 39.
Canada: Parks, 830.
Carboniferous: Stevenson, 1036.
Colorado, Apishapa quadrangle: Stose, 1056.
Geologic history—Continued.
Connecticut: Lull, 688.
central: Barrell, 47.
Costa Rica: Romanes, 931.
Greenland, Julianehaab region: Ussing, 1130.
Idaho: Umpleby, 1125.
Illinois, Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Kentucky, Kenova quadrangle: Phalen, 850.
Lake Champlain: Perkins, 845.
Maryland: Md. G. S., 724.
Choptank quadrangle: Miller, 758.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Nevada, Contact district, Elko Co.: Schrader, 955.
New Brunswick, Bathurst district: Young, 1258.
New Mexico, Santa Rita region: Paige, 821.
New York, Devonian: Smith, 990.
North Carolina, Coastal Plain: Clark *et al.*, 193.
North Dakota, Bismarck quadrangle: Leonard, 654.
Ohio, Kenova quadrangle: Phalen, 850.
Oklahoma, northeastern: Snider, 1005.
Talihina region: Woodworth, 1249.
Oregon, Crater Lake: Diller, 282.
Pennsylvania, Claysville quadrangle: Munn, 782.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Quebec, southern: Dresser, 288.
South Dakota, south central: Perisho and Visher, 843.
Texas, Llano and Burnet quadrangles: Paige, 817.
Tertiary, Montana-Idaho-Washington: Hershey, 451.
United States: Blackwelder, 76.
Utah: Umpleby, 1125.
Park City district: Boutwell, 92.
Vermont, Irasburg: Richardson and Conway, 906.
Virginia, Carboniferous: Branson, 103.
Coastal Plain: Clark and Miller, 192.
Washington, Index mining district: Weaver, 1168.
western: Weaver, 1169.
West Virginia, Kenova quadrangle: Phalen, 850.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Wisconsin: Hotchkiss and Thwaites, 501.
Green Lake County: Alden, 6.
Wyoming, Cenozoic: Baker, 40.
Cody region: Sinclair, 983, 984.
Yellowstone National Park: Hague, 417.
Yukon, Wheaton district: Cairnes, 149.

Geologic maps.
Alabama, Coosa coal field: Prouty, 873.
Alaska, Alaska Range glaciers: Capps, 172.
Alatna-Noatak region: Smith, 998.
Bonnifield region: Capps, 170.
Bremner River region: Moffit, 770.
Copper River glaciers: Martin, 723.
Copper River region: Moffit, 769.
Gulkana-Susitna region: Moffit, 769.
Hanagita Valley: Moffit, 770.
Iliamna region: Martin and Katz, 721.
Juneau gold belt: Knopf, 594.
Matanuska Valley: Martin and Katz, 722.
Rampart and Hot Springs regions: Eakin, 297.
Sitka district: Knopf, 595.
Yentna district: Capps, 171.
Yukon River (upper) region: Prindle and Mertie, 869.
Alberta: Ries and Keele, 916.
Arctic regions (part): Bugge, 127.
Arizona, Silverbell district: Stewart, 1037, 1039.
British Columbia, Boundary district: LeRoy, 655.
Observatory Inlet: McConnell, 694.
Portland Canal mining district: McConnell, 695, 696.
Skagit Valley, Yale district: Camsell, 164.
Vancouver Island: Clapp, 182; Clapp and Allan, 185.
Nanaimo sheet: Clapp, 183.
southern: Clapp, 182.
California, Eagle Mountain district: Harder, 428.
San Joaquin Valley: Anderson, 15.
Shasta Co., Harrison Gulch: Kramm, 607.
Canada: Canada G. S., 169.
Colorado, Alma district: Patton *et al.*, 834.
Apishapa quadrangle: Stose, 1056.
Cebolla district: Singewald, 988.
Denver-Colorado Springs region: Richardson, 908.
glacial deposits: Atwood and Mather, 32.
Connecticut, central: Barrell, 47.
Florida, physiographic: Sellards, 961.
Georgia, Appalachian Valley and Cumberland Plateau: Maynard, 738.
Greenland, Julianehaab region: Ussing, 1130.
Illinois: Ill. G. S., 531.
Marion County oil fields: Blatchley, 79.
Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Peoria quadrangle: Udden, 1117.
Wheaton quadrangle: Trowbridge, 1104.
Iowa: Norton *et al.*, 800.

Geologic maps—Continued.
Kansas: Parker, 826.
Kentucky, eastern: Miller, 756.
Kenova quadrangle: Phalen, 850.
Manitoba: Ries and Keele, 916.
Maryland, Choptank quadrangle: Miller, 758.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Michigan, Isle Royale: Lane, 627.
Missouri: Crane, 233.
Montana, Baker field, Custer Co.: Bowen, 93.
Butte district: Weed, 1171.
Culbertson field, Valley Co.: Beekly, 63.
Custer Co., Terry lignite field: Herald, 448.
Dawson Co., Glendive lignite field: Hance, 426.
eastern: Calvert, 157.
Electric coal field, Park Co.: Calvert, 159.
Glacier National Park, Pleistocene deposits: Alden, 5.
Livingston and Trail Creek coal fields: Calvert, 158.
Sidney field, Dawson Co.: Stebinger, 1026.
Nevada, Jarbidge, Contact, and Elk Mountain mining districts: Schrader, 955.
New Brunswick, Albert and Westmoreland counties: Ells and Ells, 308.
Nipisiguit iron-ore deposit: Young, 1258.
New Madrid earthquake: Fuller, 343.
New Mexico, Santa Rita region: Paige, 821.
Tijeras field, Bernalillo Co.: Lee, 646.
New York, Hudson River (lower) region: Hovey, 505.
Nicaragua, Pis-Pis district: Hershey, 450.
North America: Willis, 1212.
North Carolina, Coastal Plain: Clark *et al.*, 193.
Dan River coal field: Stone, 1046.
North Dakota, Bismarck quadrangle: Leonard, 654.
Nova Scotia: Rickard, 911.
Hall Harbour sheet: Canada G. S., 167.
Kingsport sheet: Canada G. S., 168.
Ohio, Columbus quadrangle: Stauffer *et al.*, 1025.
Kenova quadrangle: Phalen, 850.
peat deposits: Dachnowski, 248.
southwestern: Fuller and Clapp, 346.
Pleistocene: Fuller and Clapp, 346.
Oklahoma, northeastern, Mississippian-Pennsylvanian contact: Snider, 1005.

Geologic maps—Continued.
Ontario, Eagle Lake area: Parsons, 832.
Gowganda to Porcupine area: McMillan, 709.
Larder Lake district: Wilson, 1220.
Point Mamainse: Lane, 628.
Porcupine area and Temiskaming district: Burrows, 137.
Sudbury district, West Shiningtree area: Collins, 218.
Oregon, road materials: Parks, 827.
Pennsylvania, Center County (part): Ziegler, 1262.
Claysville quadrangle: Munn, 782.
Lehigh and Northampton counties: Peck, 839.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
South Mountain: Eaton, 303.
Quebec, Patricia district: Anon., 1270.
Pontiac County: Wilson, 1220.
southern: Dresser, 288.
Saskatchewan: Ries and Keele, 916.
South Dakota, Mellette, Washabaugh, Bennett, and Todd counties: Perisho and Visher, 843.
Tennessee, Tuckahoe district: Gordon and Jarvis, 383.
Texas, Electra and Petrolia oil and gas fields: Udden and Phillips, 1121.
Llano and Burnet quadrangles: Paige, 817.
Utah, Park City district: Boutwell, 92.
San Juan oil field: Woodruff, 1243.
Uinta Co., Deep Creek district: Lupton, 689.
Wasatch Co., Blacktail Mountain coal field: Lupton, 690.
Vermont, Albany: Richardson and Collister, 905.
Craftsbury: Richardson, 904.
Irasburg: Richardson and Conway, 906.
Virginia, Coastal Plain: Clark and Miller, 192.
middle eastern: Watson and Hess, 1165.
Washington, Index district: Weaver, 1168.
King County: Evans, 313.
western: Weaver, 1169.
West Virginia, Doddridge and Harrison counties: Hennen, 447.
Kenova quadrangle: Phalen, 850.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Wisconsin: Hotchkiss and Thwaites, 501.
west end of Lake Superior: Thwaites, 1085.
Wyoming, Douglas oil field, Converse Co.: Jamison, 539.
Lost Spring coal field: Winchester, 1231.

Geologic maps—Continued.
Wyoming—Continued.
Muddy Creek oil field, Carbon Co.: Jamison, 539.
Powder River oil field: Wegemann, 1178.
Salt Creek oil field, Natrona Co.: Jamison, 540.
Sussex coal field: Wegemann, 1179.
Wind River region: Woodruff and Winchester, 1246.
Yukon, Wheaton district: Cairnes, 149.
Geologic time.
General: Wright, 1256.
Erosion in Indiana: Culbertson, 241.
Postglacial erosion and oxidation: Fairchild, 317.
Geological surveys. *See* Surveys.
Geomorphogeny. *See* Physiographic.
Geomorphology. *See* Physiographic.
Geophysical research: Day, 274.
Georgia.
Economic.
Limestones and cement materials: Maynard, 738.
Stratigraphic.
Northern Georgia: Maynard, 738.
Paleontology.
Echinids, Tertiary: Stefanini, 1028.
Mineralogy.
Graves Mountain: Watson and Watson, 1166.
Native gold with sillimanite: Watson, 1162.
Geothermic gradients and petroleum: Shaw, 971.
Geysers.
General: Weed, 1172.
Yellowstone National Park: Hague, 417.
Glacial deposits, Alaska: Tarr and Martin, 1067.
Glacial deposits east of Cody, Wyoming: Sinclair, 984.
Glacial geology.
General: Wright, 1256.
Contact plane between Nebraskan and Kansan drifts: Carman, 173.
Loess, relations to drift: Keyes, 572.
Alaska: Tarr, 1063; Tarr and Martin, 1067.
northwestern: Smith, 997.
Colorado, San Juan Mountains: Atwood and Mather, 32; Hopkins, 492.
Colorado, Telluride quadrangle: Hole, 485.
Idaho, northern: Hershey, 451.
Illinois, Wheaton qaudrangle: Trowbridge, 1104.
Indiana: Shannon, 966.
Iowa: Shimek, 977.
Little Sioux Valley: Carman, 174.
Sioux Falls region: Shimek, 976.
Montana, Glacier National Park: Alden, 5.

Glacial geology—Continued.
Montana—Continued.
western: Hershey, 451.
Nebraska, northeastern: Todd, 1088.
New York: Fairchild, 315, 316; Spencer, 1009.
Black and Mohawk valleys: Fairchild, 314.
Overlook Mountain: Stevens, 1034.
western: Taylor, 1072.
Ohio, Columbus quadrangle: Stauffer *et al.*, 1025.
Ontario, Porcupine: Hore, 494.
southwestern: Taylor, 1071.
South Dakota: Shimek, 977.
Sioux Falls: Shimek, 976.
southeastern: Todd, 1088.
Wisconsin, Green Lake County: Alden, 6.
Wyoming, Cody region: Sinclair, 983.
Glacial lakes. *See also* Beaches; Shore lines; Terraces.
Lake, Chicago: Baker, 41.
New York: Fairchild, 315, 316.
Black and Mohawk valleys: Fairchild, 314.
Lake Aplaus: Clarke, 198.
Vermont: Perkins, 845.
Glacial period. *See* Glacial geology.
Glaciers.
General.
Crescentic fractures, formation of: Lahee, 616.
Motion: Tarr, 1065.
Properties of ice: Tarr and Rich, 1068.
Alaska: Martin, 723; Tarr, 1063.
Alaska Range: Capps, 172.
Yakutat Bay: Tarr, 1065; Tarr and Martin, 1066.
British Columbia, Sir Sandford glacier, 1911: Palmer, 825.
Greenland: Koch and Wegener, 603.
Washington, Mt. Rainier: Matthes, 729.
Glass sand.
United States: U. S. G. S., 1127.
West Virginia, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Glendive lignite field, Dawson Co., Mont.: Hance, 426.
Globidens alabamaensis: Gilmore, 365.
Glytodont from Mexico: Brown, 118, 121.
Gold.
General.
Transportation and deposition in nature: Lenher, 653.
Alaska, Bonnifield region: Capps, 170.
Bremner River district: Moffit, 770.
Chitina district: Moffit, 771.
Eagle River region: Knopf, 594.
Fairbanks and Circle districts: Ellsworth, 309.
Fortymile, Eagle, and Seventymile River districts: Porter, 866.
Gold—Continued.
Alaska—Continued.
Iliamna region: Martin and Katz, 721.
Kenai Peninsula, Seward-Sunrise region: Johnson, 549.
Rampart and Hot Springs regions: Eakin, 297.
Ruby district: Maddren, 711.
Seward Peninsula: Smith, 999.
Sitka district: Knopf, 595.
Valdez district: Brooks, 114; Storm, 1050.
Woodchopper and Fourth of July Creeks: Prindle and Mertie, 869.
Yentna district: Capps, 171.
Arizona, Owl Head district: Pickard, 856.
British Columbia, Fraser Canyon, Siwash Creek area: Bateman, 57.
Lillooet division, Yale district: Camsell, 163.
Nelson area: LeRoy, 656.
Skagit Valley, Yale district: Camsell, 164.
Vancouver Island: Clapp, 182.
California, High Grade district: Stines, 1041, 1042; Storms, 1052.
Los Burros district: Davis, 268.
Placer Co., Helester mines: Storms, 1054.
Shasta Co., Harrison Gulch: Kramm, 607.
Colorado, Alma district: Patton *et al.*, 834.
Breckenridge placers: Lakes, 619.
Leadville: Butler, 144.
Newlin's Gulch: Butler, 147.
Summit Co.: Brown, 122.
Mexico, Sonora, Sonora Valley: Hafer, 415.
Michigan: Allen *et al.*, 13.
Montana, Butte district: Weed, 1171.
Elkhorn, magmatic sulphide ore body: Knopf, 597.
Nevada, Goldfield: Locke, 676.
Jarbidge district: Schrader, 955.
National mining district: Winchell, 1224.
Palmyra district: Cutler, 247.
New Mexico, Grant Co.: Pickard, 855.
Santa Fe Co.: Statz, 1019.
Nicaragua, Chontales mining district: Feust, 324.
Nova Scotia: Rickard, 911.
Medway River basin: Faribault, 318.
Ontario, Lake of the Woods field: Parsons, 832.
Larder Lake district: Wilson, 1220.
McArthur township: Hopkins, 491.
Porcupine region: Baelz, 34; Burrows, 137; MacLean, 707.
Swastika area: Bruce, 123.
West Shiningtree district: Collins, 218; Hodge, 481; Stewart, 1040.

Gold—Continued.
Quebec: Denis, 278.
Chaudière district: Keele, 566.
Pontiac County: Wilson, 1220.
Texas, in Eocene deposits: Dumble, 295.
Llano: McLaren, 705.
Llano and Burnet quadrangles: Paige, 817.
United States: U. S. G. S., 1127.
Yukon, Klondike district: Cairnes, 151; Lakes, 624.
Wheaton district: Cairnes, 149.
Grand Canyon district: Johnson, 552.
Granite.
New York: Newland, 798.
Vermont: Perkins, 845, 846.
Graphite.
Mexico, Santa Maria mines: Hornaday, 500.
Montana, Dillon: Bastin, 54.
New York: Newland, 798.
Pennsylvania: Miller, 759.
Chester Co.: Beattie, 59.
Quebec: Denis, 278.
Amherst: Cirkel, 181.
Ottawa Valley: Stansfield, 1018.
Texas, Llano and Burnet quadrangles: Paige, 817.
United States: Bastin, 55; U. S. G. S., 1127.
Graptolites.
New Brunswick, Dictyonema fauna: Hahn, 421.
Gravel.
New York: Newland, 798.
Oregon: Parks, 828.
United States: U. S. G. S., 1127.
Virginia, Coastal Plain: Watson, 1161.
Greenland.
General.
Julianehaab district: Ussing, 1131.
Northwestern Greenland: Heim, 442.
Dynamic and structural.
Glaciers: Koch and Wegener, 603.
Stratigraphic.
Julianehaab region: Ussing, 1130.
Northeast Greenland: Ravn, 886.
Western Greenland: Heim, 443.
Paleontology.
Jurassic and Cretaceous fossils, northeast Greenland: Ravn, 886.
Petrology.
Julianehaab region: Ussing, 1130.
Mineralogy.
Britholite: Bøggild, 85.
Cryolite, perovskite, and boracite: Bøggild, 85.
Cryolite minerals: Bøggild, 86.
Stalactitic minerals from Ivigtut: Bøggild, 87.
Groundhog coal basin, Skeena district, B. C.: Malloch, 714, 715.
Gunnison Valley, Mesa and Delta counties, Colorado: Woodruff, 1245.
Gypsum.
General.
Origin: Rogers, 924; Jones, 559.
Alaska, Sitka district: Knopf, 595.
Canada: Cole, 215.
Michigan: Allen *et al.*, 13.
Nevada, Lyon Co.: Read, 892.
New Brunswick: Kramm, 608.
Albert Co.: Bailey, 38.
New York: Newland, 798.
Oregon: Parks, 828.
United States: U. S. G. S., 1127.
Virginia, southwestern: Stose, 1057.
Gypsum, optic angle: Kraus and Youngs, 609.
Haiti.
Dynamic and structural.
Earthquake sounds: Scherer, 948.
Earthquakes: Scherer, 947.
Hancock quadrangle, Maryland-West Virginia-Pennsylvania: Stose and Swartz, 1058.
Hanging valleys.
New York: Spencer, 1009.
Hardness, dark scale: Lane, 631.
Hawaiian Islands.
Dynamic and structural.
Kilauea: Penck, 841.
Volcanoes: Komorowicz, 606.
Volcanoes, succession in age: Jaggar, 538.
Mineralogy.
Gabbro, minerals from: Schaller, 936.
Hetch Hetchy Valley: Matthes, 728.
High Grade district, California: Stines, 1041, 1042.
History, philosophy, etc. *See also* Surveys.
General: Westgate, 1183.
California surveys: Storms, 1055.
Recent developments in geology: Butler, 143.
Tennessee, geology: Glenn, 373.
Vertebrate paleontology: Sinclair, 982.
Holothurians, fossil: Clark, 190.
Honduras.
Economic.
Mineral resources: Akin, 4.
Hot Springs region Alaska: Eakin, 297.
Ice age. *See* Glacial geology.
Ice ages (ancient).
Devonian: Matthew, 730.
Ice ramparts.
Nova Scotia: Brodie, 109.
Idaho.
Economic.
Cœur d'Alene region: Huston, 527.
Lead-silver ores, Wardner district: Ransome, 885.
Nitrate deposits: Gale, 348.
Report on mining industry: Bell, 64.
Dynamic and structural.
Bannock overthrust: Richards and Mansfield, 903.
Physiographic.
Erosion surface, old: Blackwelder, 77.
Kellogg region, terraces: Hershey, 451.

Idaho—Continued.
Physiographic—Continued.
Northern Idaho: Hershey, 449.
Peneplain, Tertiary: Umpleby, 1124, 1125.
Stratigraphic.
Cœur d'Alene district, Belt and Pelona series: Hershey, 452.
Prichard formation: Huston, 527.
East Idaho: Umpleby, 1123.
Mineralogy.
Opal: Kunz, 613.
Igneous and volcanic rocks. *See also* Intrusions; Magmas.
General.
Classification, field: Johnson and Tibby, 553.
Classification symbols: Cross, 239.
Grain: Lane, 627.
Quantitative classification, modifications of: Cross *et al.*, 240.
Symbols in quantitative classification: Cross, 239.
Alaska, Bonnifield region: Capps, 170.
Gulkana-Susitna region: Moffit, 769.
Iliamna region: Martin and Katz, 721.
Matanuska Valley: Martin and Katz, 722.
Sitka district: Knopf, 595.
Alaska-Yukon boundary: Cairnes, 150.
Arctic regions: Bugge, 127.
Arizona, Silverbell district: Stewart, 1037.
British Columbia: Camsell, 162.
Beaverdell area, Yale district: Reinecke, 900.
Boundary district: LeRoy, 655.
Ice River district: Allan, 10.
Nelson area: LeRoy, 656.
Portland Canal district: McConnell, 696.
Skagit Valley, Yale district: Camsell, 164.
Skeena River region: Malloch, 715.
Vancouver Island: Clapp, 182.
West Kootenay: Drysdale, 289.
California, Eagle Mountains: Harder, 428.
El Paso Range and southern Sierra Nevada: Baker, 39.
Colorado, Alma district: Patton *et al.*, 834.
Apishapa quadrangle: Stose, 1056.
Grand Mesa and West Elk Mountains: Lee, 647.
Connecticut, Preston region: Loughlin, 680.
Costa Rica: Romanes, 931.
Peninsula of Nicoya: Romanes, 932.
Georgia, Graves Mountain: Watson and Watson, 1166.
Greenland, Julianehaab region: Ussing, 1130.
western: Heim, 443.
Kentucky, Kenova quadrangle, Elliott Co.: Phalen, 850.
Igneous and volcanic rocks—Continued.
Mexico, Rio Verde region: Waitz, 1143.
Matehuala, San Luis Potosi: Spurr *et al.*, 1016.
Missouri, Ozark region: Crane, 233.
Montana, Butte district: Weed, 1171.
Nevada, Elko Co.: Schrader, 955.
New Mexico, northeastern: Lee, 650.
Santa Rita region: Paige, 821.
New York: Hartnagel, 432.
Nicaragua, northeastern: Hershey, 450.
North Carolina, Dan River field: Stone, 1046.
Nova Scotia, Arisaig-Antigonish district: Williams, 1211.
Ontario, Gowganda to Porcupine area: McMillan, 709.
Pennsylvania: Miller, 759.
Quebec: Valiquette, 1132.
Keekeek and Kewagama lakes region: Bancroft, 43.
Rhode Island, Narragansett Basin: Lahee, 617.
Texas, Llano and Burnet quadrangles: Paige, 817.
Utah, Marysville district: Butler and Gale, 141.
Park City district: Boutwell, 92.
San Juan oil field: Woodruff, 1243.
Vermont, Craftsbury: Richardson, 904.
Irasburg: Richardson and Conway, 906.
Washington, Index district: Weaver, 1168.
King County: Evans, 313.
Wyoming, Leucite Hills, Sweetwater Co.: Schultz and Cross, 957.
Igneous intrusion. *See* Intrusion.
Illinois.
General.
Mining and State geological survey: DeWolf, 280.
Economic.
Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Oil fields: Blatchley, 81; Wheeler, 1185.
Carlinville: Kay, 563.
Carlyle: Shaw, 970.
Crawford and Lawrence counties: Blatchley, 80.
structure: Blatchley, 83.
Oil industry: Blatchley, 82.
Oil investigations: Blatchley, 79.
Peoria quadrangle: Udden, 1117.
Portland-cement resources: Bleininger *et al.*, 84.
Sand-lime brick: Parr and Ernest, 831.
Physiographic.
Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Stratigraphic.
Carboniferous: Blatchley, 79.
Carlyle oil field: Shaw, 970.
Channahon and Essex limestones: Savage, 935.

Illinois—Continued.
Stratigraphic—Continued.
Geologic map: Ill. G. S., 531.
Mazon Creek shales: Moodie, 775.
Murphysboro and Herrin quadrangles: Shaw and Savage, 972.
Peoria quadrangle: Udden, 1117.
Sangamon County: Crook, 234.
Sweetland Creek shale: Udden, 1118.
Wheaton quadrangle: Trowbridge, 1104.
Wilmette Bay, Glacial Lake Chicago: Baker, 41.
Underground water.
Peoria quadrangle: Udden, 1117.
Incerta sedes.
Steeprock fauna, Ontario: Walcott, 1151.
Iliamna region, Alaska: Martin and Katz, 721.
Indiana.
General.
Driftless area, geology: Cumings, 244.
Glaciation and soils: Barrett, 49.
Soil survey, Greene County: Tharp and Mann, 1074.
Hancock, Johnson, and Shelby counties: Hole, 484.
Laporte, St. Joseph, and Bartholomew counties: Quinn, 882.
Marion County: Geib and Schroeder, 360.
Morgan and Owen counties: Edmonson, 306; Shannon, 965.
Posey Co.: Marean, 717.
Spencer, Warrick, and Scott counties: Mangum and Neill, 716.
Dynamic and structural.
New Albany shale, jointing: Culbertson, 242.
Physiographic.
Glaciation, results: Shannon, 966.
Sand areas: Shannon, 967.
Southern Indiana: Cumings, 244.
Terraces of Whitewater River: Hole, 483.
Stratigraphic.
Arnheim formation: Foerste, 328.
Pleistocene age: Hay, 435.
Paleontology.
Batostomas, Richmond series: Cumings and Galloway, 245.
Cincinnatian and Mohawkian fossils: Foerste, 327.
Naticopsis, coloration: Girty, 369.
Pleistocene vertebrates: Hay, 435.
Underground water.
Southern Indiana: Cumings, 244.
Insecta.
Cockroaches, Texas: Cockerell, 212.
Colorado, Florissant: Muttkowski, 789.
Coleoptera: Wickham, 1202, 1203.
Raphidia: Cockerell, 211.
Odonata: Ris, 919.
Pierre formation, Petropteron: Cockerell, 210.
Scudder's work: Cockerell, 207.
Tertiary fungus gnat: Johannsen, 548.
Intrusions. *See also* Dikes; Igneous and volcanic rocks; Laccoliths; Magmas.
Connecticut, Preston region: Loughlin, 680.
Invertebrata (general). *See also* Anthozoa; Brachiopoda; Crustacea; Echinodermata; Foraminifera; Insecta; Mollusca; Problematica; Spongida; Vermes.
California, Miocene: Smith, 996.
Cambrian, British Columbia: Walcott, 1154.
Canada, Ordovician: Raymond, 888.
Colorado, Lykins fauna: Girty, 368.
Connecticut, Triassic: Lull, 688.
Devonian, Allegheny region: Kindle, 581.
Jurassic and Cretaceous fossils, Greenland: Ravn, 886.
Miocene fossils from Springvale, Trinidad: Guppy, 409, 410.
North Carolina, fossils from Wilmington: Brown and Pilsbry, 117.
Ontario, Oriskany sandstone: Stauffer, 1024.
Silurian, Maine, Eastport quadrangle: Williams, 1209.
Stromatoporoids and Eozoon: Kirkpatrick, 588, 589.
Triassic, Arctic regions: Kittl, 590.
Trinidad, Tertiary: Maury, 736.
Iowa.
General.
History of geology in Iowa: Arey, 23.
Report State geologist: Kay, 562.
Economic.
Mineral production, 1909 and 1910: Iowa G. S., 533.
Stratigraphic.
General: Norton *et al.*, 800.
Carboniferous, base: Keyes, 578.
Cedar Valley-Lime Creek unconformity: Thomas, 1076.
Geologic section, subdivisions: Keyes, 577.
Nebraskan drift of Little Sioux Valley: Carman, 174.
Pleistocene formations: Shimek, 977.
Sioux Falls region: Shimek, 976.
Salem limestone: Van Tuyl, 1136.
Sweetland Creek shale: Udden, 1118.
Paleontology.
Aftonian mammals: Thomas, 1077.
Edestus: Hay, 438.
Lepidostrobus, Warren Co.: Tilton, 1086.
Underground water.
General: Norton *et al.*, 800.
Irasburg terranes, Vermont: Richardson and Conway, 906.
Iridium.
United States: U. S. G. S., 1127.
Iron.
General.
Geology in iron ore exploration: Leith, 651.
Iron ore reserves: Eckel, 305.

Iron—Continued.
General—Continued.
Magnetic iron ores: Nason, 791.
Origin · Singewald, 986.
Alabama: Phillips, 853.
Alberta, Blairmore area: Leach, 643.
British Columbia, Vancouver Island: Clapp, 182.
California, Eagle Mountains: Harder, 428.
Colorado, Boulder Co.: Jennings, 544.
Cebolla district, Gunnison Co.: Singewald, 988.
Cuba, Mayari district: Guardiola, 406.
Kentucky, Clinton ores: Whinery, 1192.
Hartford quadrangle: Gardner, 355.
Kenova quadrangle: Phalen, 850.
Lake Superior ores, origin: Winchell, 1229.
Michigan: Allen *et al.*, 13.
Cascade iron range: McDonald, 701.
eastern: Goetz, 377.
Minnesota: Van Barneveld, 1133; Zapffe, 1260.
Cuyuna range: Thomas, 1079.
Mississippi, Marshall and Benton counties: Lowe, 683.
Missouri: Crane, 233; Wittich, 1236.
New Brunswick, Bathurst district: Young, 1258.
New York: Newland, 798.
Cheever mines, Port Henry: Stoltz, 1044.
Ontario mine: Taylor and Booth, 1070.
Staten Island: Fettke, 323.
Nova Scotia, Torbrook: Fréchette, 339.
Ontario, Porcupine area: Burrows, 137.
Pennsylvania, Durham: Bayley, 58.
Quebec: Denis, 278.
north of the St. Lawrence: Dulieux, 290, 291.
northwestern: Bancroft, 43.
Saguenay Co., Natashkwan: Mackenzie, 704.
St. Lawrence, titaniferous ores: Dulieux, 292.
Tennessee, Clinton ores: Whinery, 1192.
east: Jarvis, 541.
Tuckahoe district: Gordon and Jarvis, 383.
Texas, Llano and Burnet quadrangles: Paige, 817.
United States: Guillotel, 407; U. S. G. S., 1127.
Utah, Union Chief and Santaquin mines: Higgins, 461.

Isostasy.
General: Hayford, 440; Hayford and Bowie, 441; Putnam, 881.
Gravity anomalies, relation to geologic formations: Bowie, 98.
Gravity reduction: Bowie, 100.
Topography and isostatic compensation: Bowie, 97.

Jamaica.
Dynamic and structural.
Earthquake of 1907: Cornish, 226.

Jointing.
General: Sheldon, 974.
Jarbidge mining district, Elko Co., Nev.: Schrader, 955.

Judith River formation, position and age: Peale, 837.

Jurassic.
Stratigraphy.
Alaska: Martin, 720.
Gulkana-Susitna region: Moffit, 769.
Iliamna region: Martin and Katz, 721.
Matanuska Valley: Martin and Katz, 722.
Alberta, Blairmore area: Leach, 643.
Roche Miette area: Dowling, 285.
British Columbia, Nelson area: LeRoy, 656.
Skeena River region: Malloch, 715.
Vancouver Island: Clapp, 182.
Nanaimo sheet: Clapp, 183.
Colorado, Grand Mesa and West Elk Mountains: Lee, 647.
Greenland, northeast: Ravn, 886.
Mexico, Durango, San Pedro del Gallo: Burckhardt, 133.
Montana, Electric coal field: Calvert, 159.
North America: Willis, 1212.
South Dakota, Black Hills: Stone, 1045.
Utah, San Juan oil field: Woodruff, 1243.
Park City district: Boutwell, 92.
Wyoming, Black Hills: Stone, 1045.
Douglas oil field, Converse Co.: Jamison, 539.
Powder River oil field: Wegemann, 1178.
Salt Creek oil field, Natrona Co.: Jamison, 540.
Yukon, Wheaton district: Cairnes, 149.
Paleontology.
Dinosaurs: Holland, 487.
Greenland, northeast: Ravn, 886.
Mexico, San Pedro del Gallo: Burckhardt, 133.
Wyoming, frog: Moodie, 776.
plesiosaurs: Mehl, 741.

Kansas.
Stratigraphic.
General: Parker, 826.
Mineralogy.
Meteorite, Scott City: Merrill, 749.
Underground water.
General: Parker, 826.

Kaolin.
Quebec, Huberdeau: Ries, 915.

Katalla oil field, Alaska: Thompson, 1081.

Kenai Peninsula, mineral resources: Brewer, 106.

Kentucky.
General.
Dix River region: Foerste, 326.
Report of survey, 1911: Norwood, 801.

Kentucky—Continued.
Economic.
Black Mountain coal district: Dilworth, 284.
Campton oil pool: Munn, 783.
Clinton iron-ore deposits: Whinery, 1192.
Coal field, Pineville Gap: Crandall and Sullivan, 232.
Coals, Licking Valley region: Crandall, 231.
Cumberland coal field: Hodge, 480.
Eastern coal field: Miller, 756.
Hartford quadrangle: Gardner, 355.
soils: Jones, 560.
Kentucky River, three forks, coals: Hodge, 479.
Knox Co., oil and gas: Munn, 784.
Phosphate: Gardner, 356; Waggaman, 1141.
Quicksand creeks region, coal: Fohs, 330.
Tradewater River coal region: Glenn, 371.
Webster Co.: Glenn, 372.
Dynamic and structural.
Colossal Cavern: Hovey, 511.
Mammoth Cave: Hovey, 510, 511; Turner, 1112.
bibliography: Hovey, 512.
Physiographic.
Kenova quadrangle: Phalen, 850.
Stratigraphic.
Arnheim formation: Foerste, 328.
Campton oil pool: Munn, 783.
Chattanooga shale, unconformity at base: Kindle, 582.
Chattanoogan series: Ulrich, 1122.
Kenova quadrangle: Phalen, 850.
Knox Co.: Munn, 784.
Webster Co.: Glenn, 372.
Paleontology.
Cincinnatian and Mohawkian fossils: Foerste, 327.
Kenova quadrangle, Kentucky-West Virginia-Ohio: Phalen, 850.
Keweenaw series of Michigan: Lane, 627.
Koyukuk-Kobuk region, Alaska: Smith, 1001.
Lagomorpha: Gidley, 363.
Lake Superior iron ores: Winchell, 1229.
Lakes. *See also* Glacial lakes.
Idaho, Cœur d'Alene: Hershey, 451.
New York: Spencer, 1009.
Oregon, Crater Lake: Diller, 282.
Lakes, glacial. *See* Glacial lakes.
Larder Lake district, Ontario: Wilson, 1220.
Landslides.
General: Lakes, 621.
Alberta, Frank, Turtle Mountain: Daly *et al.*, 257.
Panama, Culebra Cut: MacDonald, 700.
Wyoming, Gros Ventre slide: Blackwelder, 78.
Lava.
Origin: Hobbs, 477.
Lead.
Arizona, Castle Dome district: Nevius, 797.
Silverbell district: Stewart, 1037.
British Columbia, East Kootenay: Schofield, 953, 954.
Colorado, Leadville: Butler, 144.
Idaho, Cœur d'Alene region: Huston, 527.
Wardner district: Ransome, 885.
Mexico, Sierra Mojada district: Van Horn, 1135.
New Mexico, Magdalena district: Tuttle, 1113.
Oklahoma, Miami district: Chapman, 180.
northeastern: Snider, 1005.
Quebec: Denis, 278.
Tennessee: Nelson, 794.
Texas, Llano and Burnet quadrangles: Paige, 817.
United States: U. S. G. S., 1127.
Utah, Park City district: Boutwell, 92.
Union Chief and Santaquin mines: Higgins, 461.
Yukon, Wheaton district: Cairnes, 149.
Lepidostrobus, Warren County: Tilton, 1086.
Lignite. *See also* Coal.
North Dakota, Bismarck quadrangle: Leonard, 654.
Tennessee, west: Nelson, 795.
Lillooet mining division, British Columbia: Camsell, 163.
Lime.
Oregon: Parks, 828.
United States: U. S. G. S., 1127.
Limestone.
Georgia, north: Maynard, 738.
New York: Newland, 798.
Limnoscelis, a Cotylosaur reptile: Williston, 1214.
Lithia deposits, Black Hills: Anderson, 14.
Little Powder River coal field, Campbell County, Wyoming: Davis, 269.
Livingston coal field, Montana: Calvert, 158.
Llano and Burnet quadrangles, Texas: Paige, 817.
Loess.
General: Shimek, 978.
Origin: Keyes, 572.
Lorandite from the Rambler mine, Wyoming: Rogers, 923.
Lost Spring coal field, Converse County, Wyoming: Winchester, 1231.
Louisiana.
General.
Salines as geologic chronometer: Lachmann, 614.
Economic.
Dome theory: Lucas, 685.
Oil concentration about salt domes: Harris, 429.
Oil fields: Wooton, 1251.

Louisiana—Continued.
Economic—Continued.
Salt mines: Wooton, 1250.
Sulphur and sulphur oil deposits of Coastal Plain: Lucas, 684.
Lower Silurian. *See* Ordovician.
Lykins fauna: Girty, 368.
Magdalena district, New Mexico: Statz, 1022; Tuttle, 1113.
Magmas. *See also* Intrusions.
General: Stevens, 1033.
Formation: Wilson, 1219.
Laws of igneous emanation pressure: Stevens, 1032.
Magnesite.
United States: Gale, 352; U. S. G. S., 1127.
Magnetite.
New York, Cheever mines, Port Henry: Stoltz, 1044.
Quebec: Dulieux, 290, 291.
Maine.
General.
Penobscot River basin: Bastin, 56.
Paleontology.
Eastport quadrangle, Paleozoic faunas: Williams, 1209.
Silurian Mollusca, Washington Co.: Williams, 1207.
Mineralogy.
Herderite crystals: Ford, 336.
Mammalia.
Age of mastodon and other Proboscidea: Osborn, 809.
Artiodactyla: Peterson, 847.
Brachyostracon, new glyptodont from Mexico: Brown, 121.
California, Rancho La Brea, Carnivora: Merriam, 746.
Carnivora and Rodentia: Matthew, 731.
Cetacea, Pinnipedia, Sirenia, Zeuglodontia: True, 1107.
Craniometry of the Equidæ: Osborn, 813.
Delphinodon, Miocene, Maryland: True, 1105.
Diceratherium: Peterson, 849.
Dinosaur from Edmonton Cretaceous: Brown, 120.
Edentates, ancestry: Matthew, 734.
Eocene horses: Matthew, 732.
Equidæ, craniometry: Osborn, 813.
Hapalops: Matthew, 734.
Horns, phylogeny and ontogeny: Osborn, 816.
Iguanodont dinosaur Trachodon: Osborn, 812.
Indiana, Pleistocene: Hay, 435.
Insectivora: Gregory, 397.
Iowa, Aftonian: Thomas, 1077.
Lagomorpha: Gidley, 363.
Marsupialia: Gregory, 397.
Mastodon remains, Nova Scotia: Piers, 859.
Nebraska, rhinoceros from Miocene: Cook, 222, 223, 225.
Perissodactyla: Gidley, 362.
Mammalia—Continued.
Pleistocene faunas: Hay, 437.
Primates: Gregory, 397.
Quadrupedal locomotion: Gregory, 398.
Rancho La Brea fauna, Canidæ: Merriam, 745.
Rodents, Pleistocene, California: Kellogg, 569.
Stenomylins: Peterson, 848.
Titanothere restoration: Gregory, 400.
Titanotheres, Uinta formations: Riggs, 917.
Titanotheroid from Uinta basin Eocene: Gregory, 399.
Trachodontidæ, osteology of manus: Brown, 119.
Tyrannosaurus and Allosaurus: Osborn, 811.
Whales allied to Balænoptera: True, 1106.
Mammoth Cave, Kentucky: Hoyey, 511; Turner, 1112.
Man, fossil.
Early man in America: Volk, 1139.
Origin and antiquity: Wright, 1255.
Manganese.
New Brunswick, Bathurst district: Young, 1258.
Texas, Llano and Burnett quadrangles: Paige, 817.
United States: U. S. G. S., 1127.
Manitoba.
Economic.
Clay and shale deposits: Ries and Keele, 916.
Stratigraphic.
Ripple-marked limestone: Kindle, 584.
Manitoulin area of Lake Huron: Foerste, 329.
Map making. *See* Cartography.
Maps. *See* Geologic maps.
Marble.
New York: Newland, 798.
Tennessee: Gordon, 380.
Vermont: Dale, 250; Perkins, 845, 846.
Marl.
Virginia, Coastal Plain: Watson, 1161.
Maryland.
General.
Mineral exhibit: Md. G. S., 724.
Report of geological survey: Clark, 191.
Economic.
Choptank quadrangle: Miller, 758.
Georges Creek coal field: Hall, 423.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Physiographic.
Choptank quadrangle: Miller, 758.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Stratigraphic.
Choptank quadrangle: Miller, 758.
Onondaga formation: Kindle, 581.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Paleontology.
Delphinodon, Miocene: True, 1105.

Massachusetts.
Dynamic and structural.
Coastal marshes south of Cape Cod: Davis, 266, 267.
Stratigraphic.
Worcester phyllite, age: White, 1194.
Petrology.
Neponset Valley petrographic province: Bascom, 51.
Mineralogy.
Aragonite coating gravel pebbles: Lane, 630.
Mastodons.
Age, means of estimating: Osborn, 809.
Nova Scotia: Piers, 859.
Tetracaulodon ohioticum, tusk: Pohlig, 865.
Matanuska Valley, lower, Alaska: Martin and Katz, 722.
Medusæ. *See* Hydrozoa.
Meetings. *See* Associations.
Mercury. *See* Quicksilver.
Metamorphism.
General.
Hydrothermal alteration of granite: Moore, 779.
Metamorphic studies: Leith and Mead, 652.
Arizona, Silverbell district: Stewart, 1037.
British Columbia, Shuswap lakes region: Daly, 254.
California, Eagle Mountains: Harder, 428.
Mexico, San Luis Potosi, Dolores deposit: Spurr *et al.*, 1016.
Sonora, Elisa mine: Lee, 645.
Montana, Butte district: Weed, 1171.
Rhode Island, Narragansett Basin: Lahee, 617.
Utah, Park City district: Boutwell, 92.
Meteor Crater (Coon Butte), Arizona: Thomson, 1083.
Meteorites.
General: Foote Min. Co., 334.
American Museum collection: Hovey, 507.
Classification: Foote Min. Co., 334.
Holbrook, Ariz.: Foote, 333; Merrill, 750.
Kingston siderite, New Mexico: Hovey, 509.
Perryville, Mo.: Merrill, 751.
Scott City, Kans.: Merrill, 749.
Mexico.
General.
Yucatan: Huntington, 524.
Economic.
Hidalgo, mining industry: Gonzalez *et al.*, 379; Grothe and Salazar, 405.
Mexico, mining industry: Grothe and Salazar, 405.
Oil fields: Skertchly, 989.
Petroleum: Hornaday, 499.
in northeastern Mexico: Garfias, 357.

Mexico—Continued.
Economic—Continued.
Sahuaripa district, Sonora: Hynes, 530.
San Luis Potosi, Dolores mine, Matehuala: Spurr *et al.*, 1016.
San Nicolas mining district, Tamaulipas: Wentworth, 1182.
Santa Maria graphite mines: Hornaday, 500.
Silver, copper, and lead ores, Veta Rica mine, Sierra Mojada, Coahuila: Van Horn, 1135.
Sonora, Elisa mine: Lee, 645.
Sonora Valley mines: Hafer, 415.
Dynamic and structural.
Guadalajara earthquakes: Ordoñez, 807.
Lower California, changes of level: Wittich, 1233.
Microseisms of 1911: Mexico G. S., 753.
Petroleum, mode of accumulation: Garfias, 357.
Physiographic.
Lower California, elevated coast lines: Wittich, 1232.
Stratigraphic.
Cananea district, Sonora: Lee, 645.
Jurassic and Cretaceous of San Pedro del Gallo, Durango: Burckhardt, 133.
Tertiary deposits, eastern Mexico: Dumble, 294.
Paleontology.
Brachyostracon, new genus of glyptodonts: Brown, 121.
Glyptodont in Jalisco: Brown, 118.
Jurassic and Cretaceous faunas of San Pedro del Gallo: Burckhardt, 133.
Petrology.
Rio Verde region, Oaxaca: Waitz, 1143.
Mineralogy.
Calamine, Santa Eulalia, Chihuahua: Seebach and Paul, 959.
Gypsum crystals: Wittich and Pastor y Giraud, 1234.
Mimetesite, Chihuahua: Paul, 835.
Minerals from cave near Chihuahua: Hovey, 506.
Pseudomorphs after stibnite, San Luis Potosi: Ford and Bradley, 338.
Miami lead-zinc district, Oklahoma: Chapman, 180.
Mica.
General: Springer, 1014.
Canada: Schmid, 949.
Quebec: Denis, 278; Schmid, 951.
Ottawa Valley: Stansfield, 1018.
United States: U. S. G. S., 1127.
Michigan.
Economic.
Cascade iron range: McDonald, 701.
Iron range, eastern Michigan: Goetz, 377.
Keweenaw Point copper range: Lane, 629.

Michigan—Continued.
Economic—Continued.
Lake Superior copper formation: Hubbard, 516, 517; Hore, 495; Meuche, 752; Rice, 902; Sperr, 1011.
Mineral resources: Allen *et al.*, 13.
Stratigraphic.
Keweenaw series: Lane, 627.
Petrology.
Keweenaw series: Lane, 627.
Milk River coal field, Choteau Co., Mont.: Pepperberg, 842.
Mine waters.
Michigan, Keweenaw series: Lane, 627.
Mineral Hill, Nevada: Toll, 1089.
Mineralogy (general). *See also* Meteorites; Technique. *For regional, see names of States. For particular minerals, see list, p. 167.*
General: Palache, 823.
Binary system: Bowen, 95.
Brun's new data on volcanism: Winchell, 1228.
Conversion of rock analyses: Mead, 739.
Dana's Manual of mineralogy: Ford, 335.
Guide to minerals: Gratacap, 394.
Gypsum, optic angle variations: Kraus and Youngs, 609.
Hardness, dark scale: Lane, 631.
Mineralogy: Phillips, 852.
Neocolemanite: Eakle, 299.
Nomenclature: Washington, 1158.
Paragenesis: Rogers, 926.
Practical field geology: Farrell, 319.
Scale of hardness: Lane, 631.
Sulphides of zinc, cadmium, and mercury: Allen and Crenshaw, 11.
Textbook: Rogers, 921.
Mineral paints.
New York: Newland, 798.
Pennsylvania: Miller, 757.
United States: U. S. G. S., 1127.
Virginia, Coastal Plain: Watson, 1161.
Mineral resources (general). *See* Economic *under the names of States.*
Mineral waters.
New York: Newland, 798.
Oregon: Parks, 828.
United States: U. S. G. S., 1127.
Minerals described. *See list, p. 167.*
Minnesota.
Economic.
Cuyuna iron range: Thomas, 1079.
Iron-bearing formation, igneous intrusion: Zapffe, 1260.
Iron ranges: Van Barneveld, 1133.
Stratigraphic.
Iron ranges: Van Barneveld, 1133.
Petrology.
Iron-bearing formation, effect of intrusion: Zapffe, 1260.
Miocene. *See* Tertiary.

Miscellaneous. *See also* Addresses.
Dynamic and structural geology, 1911: Woodworth, 1247.
Geological diagnosis: Irving, 534.
Geology in iron ore exploration: Leith, 651.
New England geological excursion: Cleland, 202, 203.
United States Geological Survey, policy: Smith, 993; Report 1911–12: Smith, 992.
Mississippi.
General.
Survey, biennial report: Miss. G. S., 767.
Economic.
Iron deposits, Marshall and Benton counties: Lowe, 683.
Paleontology.
Echinids, Tertiary: Stefanini, 1028.
Mississippi Valley: Emerson, 310.
Mississippian. *See* Carboniferous.
Missouri.
Economic.
Barytes: Wittich, 1235.
Iron ores: Crane, 233; Wittich, 1236.
Dynamic and structural.
New Madrid earthquake: Fuller, 343.
Seismology, St. Louis University: Goesse and Rueppel, 376.
Physiographic.
Columbia region: Von Engeln, 1140.
Ozark region: Crane, 233.
Stratigraphic.
Ozark region: Crane, 233.
Paleontology.
Naticopsis, growth stages: Girty, 369.
Mineralogy.
Perryville meteoric iron: Merrill, 751.
Mollusca. *See also* Cephalopoda; Gastropoda; Pelecypoda.
Maine, Washington County, Silurian: Williams, 1207.
North Carolina, fossils from Wilmington: Brown and Pilsbry, 117.
Northwest America, Mollusk fauna: Dall, 252.
Panama and Costa Rica: Dall, 253.
Silurian, Maine, Washington Co.: Williams, 1207.
Tertiary, Californian province: Hannibal, 427.
from the West: Cockerell and Henderson, 213.
Washington: Weaver, 1160.
Trinidad, Tertiary: Maury, 736, 737.
Springvale, Miocene: Guppy, 409, 410.
Molluscoidea. *See* Brachiopoda; Bryozoa.
Molybdenum.
Quebec, northwestern: Bancroft, 43.
United States: U. S. G. S., 1127.
Monazite.
United States: U. S. G. S., 1127.

Moncton map area, Westmorland and Albert counties, New Brunswick: Young, 1259.

Montana.

Economic.

Baker lignite field, Custer Co.: Bowen, 93.
Blue Bird mine, Wickes; Winchell and Winchell, 1227.
Butte district: Weed, 1171.
Butte geological report: Sales, 934.
Copper veins, Butte: Kirk, 586.
Culbertson lignite field, Valley Co.: Beekly, 63.
Electric coal field, Park Co.: Calvert, 159.
Elkhorn, magmatic sulphide ore body: Knopf, 597.
Glendive lignite field, Dawson Co.: Hance, 426.
Graphite deposits, Dillon: Bastin, 54.
Livingston and Trail Creek coal fields: Calvert, 158.
Milk River coal field, Chouteau Co.: Pepperberg, 842.
Sidney lignite field, Dawson Co.: Stebinger, 1026.
Terry lignite field, Custer County: Herald, 448.

Physiographic.

Deer Creek valley, glaciation: Hershey, 451.
Glacier National Park: Alden, 5.
Western Montana: Hershey, 449.

Stratigraphic.

Baker lignite field, Custer Co.: Bowen, 93.
Butte district: Weed, 1171.
Electric coal field, Park Co.: Calvert, 159.
Glacier National Park, pre-Wisconsin drift: Alden, 5.
Glendive lignite field, Dawson Co.: Hance, 426.
Judith River formation: Peale, 837.
Lignite fields, eastern Montana: Calvert, 157.
Livingston and Trail Creek coal fields: Calvert, 158.
Milk River coal field, Chouteau Co.: Pepperberg, 842.
Sidney lignite field, Dawson Co.: Stebinger, 1026.
Terry lignite field, Custer Co.: Herald, 448.

Paleontology.

Clymenia fauna, Devonian: Raymond, 887.
Mariacrinus? insuetus: Raymond, 890.
Olenopsis from Cambrian: Walcott, 1147.
Schœnaster? montanus: Raymond, 890.

Petrology.

Butte copper veins: Kirk, 586.

Mineralogy.

Baddeleyite: Rogers, 922.
Butte district: Weed, 1171.

Monticuliporoids, development and systematic position: Cumings, 243.
Monument Creek group: Richardson, 908.

Moraines.

Ontario, southwestern: Taylor, 1071.

Mother Lode, California: Storms, 1053.

Mud volcanoes.

Trinidad: Bosworth, 91.

Muddy Creek oil field, Carbon Co., Wyo.: Jamison, 539.
Murphysboro and Herrin quadrangles, Illinois: Shaw and Savage, 972.
Mytilus middendorfil from Alaska: Gratacap, 395.
National mining district, Nevada: Winchell, 1224.

Natural bridges.

Wyoming, eastern: Barnett, 46.

Natural gas.

General: Gould, 386; and historical: Knapp, 592.
Accumulation: Johnson, 554.
Gas and oil accumulation in Appalachian region: Munn, 788.
Quaquaversal structure: Clapp, 186.
Alabama, Fayette field: Munn, 785.
Appalachian and central states: Ashley, 24.
Kentucky, Kenova quadrangle: Phalen, 850.
Knox Co.: Munn, 784.
New Brunswick, Moncton area: Young, 1259.
New York: Newland, 798.
Michigan: Allen *et al.*, 13.
Oklahoma: Gould, 385.
Ponca City field: Ohern and Garrett, 803.
Oregon: Parks, 828.
Pennsylvania, Claysville quadrangle: Munn, 782.
Tennessee: Ashley, 26.
Memphis: Munn, 786.
Texas, Wichita and Clay counties: Udden, 1119; Udden and Phillips, 1121.
United States: U. S. G. S., 1127.
West Virginia, Doddridge and Harrison counties: Hennen, 447.

Nebraska.

Dynamic and structural.

Sandstone pinnacles: Darton, 261.

Physiographic.

Pre-Wisconsin: Todd, 1088.

Stratigraphic.

Carboniferous: Barbour, 45.

Paleontology.

Diceratherium: Peterson, 849.
Eurypterids: Barbour, 45.
Rhinoceros from Miocene: Cook, 222, 223.
Tertiary fossils of Sioux County: Cook, 224.

Nelson area, British Columbia: LeRoy, 656.
Neocalamites from Richmond coal field of Virginia: Berry, 68.

Nephelite: Foote and Bradley, 331; composition: Bowen, 94.
Nevada.
General.
Fanglomerate: Lawson, 639.
Nevada Hills: Lawson, 641.
Economic.
Austin, ores: Taylor, 1073.
Como, Palmyra mining district: Cutler, 247.
Comstock, vein systems: Smith, 991.
Ely district: Weed, 1176.
Goldfield ore deposits: Locke, 676.
Jarbidge, Contact, and Elk Mountain mining districts: Schrader, 955.
Mineral Hill: Toll, 1089.
National mining district: Winchell, 1224.
Nevada-Douglas mines, Lyon Co.: Read, 802.
Nitrate deposits: Gale, 348.
Potash: Free, 341.
Railroad Valley: Sheldon, 973.
Dynamic and structural.
Fault scarps at Genoa: Lawson, 638.
Sandstone at state prison, origin: Smith, 1003.
Physiographic.
Fault scarps at Genoa: Lawson, 638.
Stratigraphic.
Eastern Nevada, Paleozoic: Hershey, 452.
Elko Co.: Schrader, 955.
Jarbidge, Contact, and Elk Mountain mining districts: Schrader, 955.
Paleontology.
Tertiary freshwater Mollusca: Hannibal, 427.
Petrology.
National mining district: Winchell, 1224.
Mineralogy.
Dahllite, Tonopah: Rogers, 925.
Gypsum and anhydrite at Ludwig mine, Lyon Co.: Rogers, 924; Jones, 559.
Opal: Kunz, 613.
Stibnite at Steamboat Springs: Jones, 558.
Tonopah minerals: Eakle, 298, 299.
Newark group in Pennsylvania: Wherry, 1191.
New Brunswick.
Economic.
Albertite: Milner, 766.
Bathurst district: Young, 1258.
Building and ornamental stones: Parks, 829.
Coal fields: Denis, 277.
Gypsum: Kramm, 608.
Albert Co.: Bailey, 38.
Tin and topaz: Brock, 108.
Dynamic and structural.
Changes of level, postglacial: Goldthwait, 378.
Gypsum, structure: Bailey, 38.
New Brunswick—Continued.
Physiographic.
General: Ganong, 354.
Stratigraphic.
Albert and Westmorland counties: Ells and Ells, 308.
Bathurst district: Young, 1258.
Carboniferous beds: Stopes, 1049.
Devonian: Matthew, 730.
Moncton area, Westmorland and Albert counties: Young, 1259.
Southern New Brunswick: Ells, 307.
Paleontology.
Dictyonema fauna of Navy Island: Hahn, 421.
Fossils in metamorphic rocks: Ells, 307.
Newfoundland.
Physiographic.
General: Twenhofel, 1114.
Paleontology.
Psygmophyllum majus: Arber, 20, 21.
New Hampshire.
Dynamic and structural.
Northey Hill in Lisbon: Lahee, 616.
Stratigraphic.
Littleton, Blueberry Mountain: Lahee, 618.
Paleontology.
Littleton, Blueberry Mountain fossils: Lahee, 618.
New Jersey.
General.
Report State geologist: Kümmel, 611.
Economic.
Mineral industry, 1911: Kümmel, 612.
Stratigraphic.
Onondaga formation: Kindle, 581.
Paleontology.
Cretaceous, palm: Stevens, 1035.
Pityoxylon: Bailey, 37.
Pleurotomidæ: Pilsbry, 860.
New Mexico.
Economic.
Coal fields of northern central New Mexico: Lee, 648.
Cochita mining district: Statz, 1021.
Copper deposits, Santa Rita, Grant Co.: Clifford, 205.
Hell Canyon mining district: Statz, 1020.
Magdalena district: Statz, 1022; Tuttle, 1113.
Mineral resources, Jemez-Albuquerque region: Reagan, 893.
Oro Grande mine, Grant Co.: Pickard, 885.
Placers, Santa Fe Co.: Statz, 1019.
Santa Rita region: Paige, 821.
Tijeras coal field, Bernalillo Co.: Lee, 646.
Dynamic and structural.
Volcanoes, extinct: Lee, 650.
Physiographic.
Northeastern New Mexico: Lee, 650.
Silver City quadrangle: Paige, 818.

New Mexico—Continued.
Physiographic—Continued.
Toyalané and Lucero: Keyes, 574.
Stratigraphic.
Coal fields around southern end of Rocky Mountains: Lee, 649.
Northern central New Mexico: Lee, 648.
Permo-Carboniferous, northern New Mexico: Williston and Case, 1216.
Santa Rita region: Paige, 821.
Tijeras coal field, Bernalillo Co.: Lee, 646.
Paleontology.
Diadectes lentus: Case and Williston, 177.
Limnoscelis: Williston, 1214.
Mineralogy.
Azurite, Socorro City: Paul, 835.
Kingston siderite: Hovey, 509.
Turquoise, Burro Mountains: Paige, 820.
Vanadinite: Paul, 835.
Underground water.
Estancia Valley: Meinzer, 742.
New York.
General.
Report of director of science division: Clarke, 198.
Economic.
Cheever mines, Port Henry, magnetite: Stoltz, 1044.
Garnet deposits, Warren Co.: Miller, 764.
Limonite deposits of Staten Island: Fettke, 323.
Mining and quarry industry, 1911: Newland, 798.
Ontario iron mine: Taylor and Booth, 1070.
Pyrite deposits, St. Lawrence Co.: Smyth, 1004.
Dynamic and structural.
Helderberg front, structural features: Grabau, 390.
Jointing, Ithaca region: Sheldon, 974.
Physiographic.
General: Tarr, 1064.
Hanging valleys: Spencer, 1009.
Hudson River, Storm King region: Kemp, 571.
Stratigraphic.
Black and Mohawk valleys: Fairchild, 314.
Classification of geologic formations: Hartnagel, 432.
Glaciation, closing phase: Fairchild, 315, 316.
Helderberg front: Grabau, 390.
Highlands, structure: Berkey, 66.
Hudson River region: Hovey, 505.
Storm King region: Kemp, 571.
Moraines, western New York: Taylor, 1072.
Onondaga fauna: Kindle, 581.
New York—Continued.
Stratigraphic—Continued.
Overlook Mountain: Stevens, 1034.
Saratoga district: Kemp, 570.
Paleontology.
Clymenia fauna, Devonian: Raymond, 887.
Coral beds, Hamilton shale: Smith, 990.
Devonian fossils: Olsson, 805.
Eurypterida: Clarke and Ruedemann, 201.
Palæechinoidea: Olsson, 804.
Paleobotany, Cretaceous, Long Island: Hollick, 489.
Plectoceras jason: Ruedemann, 933.
Potsdam-Hoyt fauna: Walcott, 1148.
Starfishes near Saugerties: Clarke, 200.
Petrology.
Gabbro and granite in Warren Co.: Miller, 765.
Mineralogy.
Mineral localities, New York City: Whitlock, 1199.
Underground water.
Saratoga mineral springs: Kemp, 570.
Nicaragua.
General.
Chontales mining district: Feust, 324.
Stratigraphic.
Northeastern Nicaragua: Hershey, 450.
Nickel.
Ontario, Sudbury field: Coleman, 216; Hore, 496; Thomas, 1080.
United States: U. S. G. S., 1127.
Washington, San Poil district: Bancroft, 44.
Nitrate deposits: Gale, 348.
Nivation.
Alaska and Yukon: Cairnes, 153.
Nomenclature. *See also* Stratigraphic.
Cambrian: Walcott, 1149.
Faults: Reid, 897.
Glacial epochs in Rocky Mountains area: Atwood and Mather, 32.
Geography and geology, relation: Davis, 271.
Igneous rocks: Cross, 239.
Iowa, geologic section: Keyes, 577.
Mineralogy: Washington, 1158.
Physiographic terms, new: Cairnes, 152.
Quantitative classification of igneous rocks, modifications of: Cross *et al.*, 240.
Types: Burling, 136.
Unconformities: Crosby, 235.
North Carolina.
Economic.
Dan River coal field: Stone, 1046.
Emeralds: Sterrett, 1030.
Physiographic.
Coastal Plain: Clark *et al.*, 193.
Stratigraphic.
Coastal Plain: Clark *et al.*, 193.

North Carolina—Continued.
Stratigraphic—Continued.
Dan River coal field: Stone, 1046.
Paleontology.
Coastal Plain: Clark *et al.*, 193.
Fossils from Wilmington: Brown and Pilsbry, 117.
Mineralogy.
Quartz, Alexander Co.: Pogue and Goldschmidt, 864.
Underground water.
Coastal Plain: Clark *et al.*, 193.
North Dakota.
Economic.
Bismarck quadrangle: Leonard, 654.
Lignite, Fort Berthold Indian Reservation: Pishel, 861.
Physiographic.
Bismarck quadrangle: Leonard, 654.
Stratigraphic.
Bismarck quadrangle: Leonard, 654.
Fort Berthold Indian Reservation: Pishel, 861.
Nova Scotia.
General.
Lahave Valley and Starrs Point: Wright, 1257.
Rocks, distribution: Howe, 513.
Economic.
Building and ornamental stones: Parks, 829.
Coal fields: Denis, 277.
Domes: Rickard, 911.
Gold-bearing series of Medway River basin: Faribault, 318.
Scheelite: McCallum, 692.
Tin: Piers, 858.
Torbrook iron deposits: Fréchette, 330.
Dynamic and structural.
Cave, Hants Co.: Prest, 867.
Ice action near Grand Lake, Cape Breton: Brodie, 109.
Stratigraphic.
Arisaig-Antigonish district: Williams, 1211.
Hall Harbor sheet: Canada G. S., 167.
Joggins Carboniferous section: Bell, 65.
Kingsport sheet: Canada G. S., 168.
Medway River basin: Faribault, 318.
Paleontology.
Mastodon remains: Piers, 859.
Mineralogy.
Minerals of Lake Ramsey district: Piers, 858.
Observatory Inlet, British Columbia: McConnell, 694.
Ohio.
Economic.
Columbus quadrangle: Stauffer *et al.*, 1025.
Fairfield Co.: Hyde, 528.
Peat deposits: Dachnowski, 248.
Dynamic and structural.
Postglacial erosion and oxidation: Wright, 1256.
Ohio—Continued.
Physiographic.
Columbus quadrangle: Stauffer *et al.*, 1025.
Fairfield Co., Hyde, 528.
Kenova quadrangle: Phalen, 850.
Preglacial Miami and Kentucky rivers: Fenneman, 320.
Stratigraphic.
Arnheim formation: Foerste, 328.
Bedford shale: Girty, 370.
Central Ohio: Prosser, 871.
Chattanoogan series: Ulrich, 1122.
Cleveland shale, age: Cushing, 246.
Columbus quadrangle: Stauffer *et al.*, 1025.
Devonian and Mississippian formations, northeastern Ohio: Prosser, 872.
Devonian shales of northern Ohio: Kindle, 583.
Fairfield Co.: Hyde, 528.
Kenova quadrangle: Phalen, 850.
Sommerset, Perry Co., coal deposition: Hyde, 529.
Southwestern Ohio: Fuller and Clapp, 346.
Paleontology.
Cincinnatian and Mohawkian fossils: Foerste, 327.
Richmond fauna, Oxford: Williams, 1210.
Petrology.
Sands: Condit, 219.
Underground water.
Southwestern Ohio: Fuller and Clapp, 346.
Ohio shale problem: Ulrich, 1122.
Oil. *See* Petroleum.
Oil shales.
New Brunswick, Albert and Westmorland counties: Ells and Ells, 308.
Oklahoma.
General.
Director's report, 1912: Ohern, 802.
Economic.
Lead and zinc deposits: Snider, 1005.
Miami lead-zinc district: Chapman, 180.
Mineral production, 1901–1911: Ohern, 802.
Northeastern Oklahoma: Snider, 1005.
Petroleum and natural gas: Gould, 385.
Ponca City oil and gas field: Ohern and Garrett, 803.
Stratigraphic.
Caney shales, boulder beds, Talihina: Woodworth, 1249.
Northeastern Oklahoma: Snider, 1005.
Ponca City oil and gas field: Ohern and Garrett, 803.
Red beds, origin: Beede, 62.
Oligocene. *See* Tertiary.
Onondaga fauna of Allegheny region: Kindle, 581.

Ontario.
General.
Bureau of mines, report 1912: Gibson, 361.
Patricia district: Miller *et al.*, 763; Anon., 1270.
Economic.
Clay resources: Ries, 915.
Cobalt district: Hore, 497; Tyrrell, 1115.
Cripple Creek gold area: Bruce, 124.
Gold fields of Lake of the Woods, Manitou, and Dryden: Parsons, 832.
Gowganda to Porcupine area: McMillan, 709.
Larder Lake district: Wilson, 1220.
McArthur township: Hopkins, 491.
Phosphate and feldspar deposits: Schmid, 950.
Point Mamainse: Lane, 628.
Porcupine gold area: Baelz, 34; Burrows, 137; Hore, 494; MacLean, 707.
Sudbury nickel and copper deposits: Hore, 496.
Sudbury nickel field: Coleman, 216; Thomas, 1080.
Swastika gold area: Bruce, 123.
West Shiningtree gold district: Hodge, 481; Stewart, 1040.
Stratigraphic.
Archean, Rainy Lake: Lawson, 637.
Cripple Creek gold area: Bruce, 124.
Detroit River area: Nattress, 793.
Gowganda to Porcupine area: McMillan, 709.
Lake of the Woods region: Parsons, 832.
Lake Simcoe area: Johnston, 557.
Larder Lake district: Wilson, 1220.
McArthur township: Hopkins, 491.
Manitoulin area, Ordovician section: Foerste, 329.
Moraines: Taylor, 1072.
Onaping sheet: Collins, 218.
Oriskany sandstone: Stauffer, 1024.
Pleistocene deposits, southwestern Ontario: Taylor, 1071.
Porcupine gold area: Burrows, 137.
Pre-Cambrian of northern Ontario: Moore, 780.
Southwestern Ontario: Stauffer, 1023.
Steeprock Lake: Lawson, 636.
Swastika gold area: Bruce, 123.
West Shining Tree gold district: Stewart, 1040.
Paleontology.
Palæaster wilsoni: Raymond, 890.
Protopalæaster narrawayi: Raymond, 891.
Starfish with ambulacral covering plates: Hudson, 519.
Trilobites, Ottawa: Narraway, 790.
Petrology.
Swastika gold area: Bruce, 123.
Underground water.
General: Ingall, 532.

Ontario iron mine, New York: Taylor and Booth, 1070.
Onychaster, structure: Schöndorf, 952.
Onyx.
Tennessee: Gordon, 381, 382.
Oolite.
Pennsylvania, central: Ziegler, 1262.
Siliceous oolites, Pennsylvania: Moore, 778.
Ordovician.
Stratigraphy.
Alaska-Yukon boundary: Cairnes, 150.
British Columbia, Cambro-Ordovician boundary: Walcott, 1146.
British Columbia, Field area: Allan, 9.
Cincinnati region: Foerste, 327.
Arnheim formation: Foerste, 328.
Colorado, Alma district: Patton *et al.*, 834.
Georgia, northern: Maynard, 738.
Idaho, east: Umpleby, 1123.
Illinois, Peoria quadrangle: Udden, 1117.
Iowa: Norton *et al.*, 800.
Kentucky, Dix River region: Foerste, 326.
Missouri, Ozark region: Crane, 233.
New Brunswick, Bathurst district: Young, 1258.
New York: Clarke, 198; Hartnagel, 432.
North America: Willis, 1212.
Nova Scotia, Arisaig-Antigonish district: Williams, 1211.
Ohio, southwestern: Fuller and Clapp, 346.
Oklahoma, northeastern: Snider, 1005.
Ontario: Raymond, 888.
Lake Simcoe area: Johnston, 557.
Manitoulin area: Foerste, 329.
Pennsylvania, central: Ziegler, 1262.
Lehigh district: Miller, 757; Peck, 839.
South Mountain: Eaton, 303.
Quebec: Raymond, 888; Valiquette, 1132.
Orford area: Harvie, 433.
southern: Dresser, 288.
Tennessee, eastern, Tuckahoe district: Gordon and Jarvis, 383.
Texas, Llano and Burnet quadrangles: Paige, 817.
Vermont, Albany: Richardson and Collister, 905.
Craftsbury: Richardson, 904.
Green Mountain region: Perkins, 845.
Irasburg: Richardson and Conway, 906.
Sudbury outlier: Dale, 251.
West Virginia, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Paleontology.
Asaphidæ: Raymond, 889.
Brachiopoda: Walcott, 1150.
British Columbia: Walcott, 1146.

Ordovician—Continued.
Paleontology—Continued.
Cincinnati region: Foerste, 327.
Arnheim formation: Foerste, 328.
Indiana, Batostomas, Richmond series: Cumings and Galloway, 245.
New York, Plectoceras jason: Ruedemann, 933.
Ohio, Richmond fauna: Williams, 1210.
Ontario, Lake Simcoe area: Johnston, 557.
starfish: Raymond, 890.
trilobites: Narraway, 790.
Protopalæaster narrawayi: Raymond, 891.
Starfish with ambulacral covering plates: Hudson, 519.
Vermont, Green Mountain region: Perkins, 845.

Ore deposits, origin. *For ore deposits in general, see* Economic (general).
General: Miller, 761; Soper, 1007; Spurr, 1015; Stewart, 1038.
Classification of ore deposits: Weed, 1175.
Colorado, Leadville: Butler, 144, 145.
Copper, Arizona, Miami district: Weed, 1174.
Silverbell district: Stewart, 1037.
British Columbia, Boundary district: LeRoy, 655.
Michigan, Keweenaw series: Lane, 627.
Montana, Butte district: Weed, 1171.
porphyry deposits: Tovote, 1095.
Cross-fractures and ore shoots: Webber, 1170.
Examination of prospects: Gunther, 408.
Garnet, New York: Miller, 764.
Gels, gelatinous quartz, and gold-ore deposition: Hatschek and Simon, 434.
Gold deposits, Alaska: Knopf, 594.
Gold ores, Nevada, National mining district: Winchell, 1224.
Graphite, Pennsylvania: Miller, 759.
Iron, Lake Superior region: Winchell, 1220.
magnetic ores: Nason, 791.
Minnesota: Van Barneveld, 1133.
Missouri: Crane, 233.
New Brunswick, Bathurst district: Young, 1258.
New York: Fettke, 323.
Lead, British Columbia, East Kootenay: Schofield, 954.
Idaho, Wardner district: Ransome, 885.
Literature of ore deposits in 1911: Weed, 1173.
Localization of ore: Keyes, 576.
Magmatic origin, ore solutions: Tolman, 1090.

Ore deposits, origin—Continued.
Mexico, Matehuala, Dolores contact-metamorphic ore deposit: Spurr *et al.*, 1016.
Sierra Mojada district: Van Horn, 1135.
Mineral sulphides of iron: Allen *et al.*, 12.
Montana, Elkhorn, magmatic sulphide ore body: Knopf, 597.
Nevada, Comstock vein systems: Smith, 991.
Tonopah deposits: Eakle, 298.
Nitrate salts: Gale, 348.
Ocher: Miller, 757.
Ore deposition chart: Keyes, 575.
Ore shoots, decrease in value with depth: Garrison, 358; Hore, 493.
Original source of metalliferous ores: Miller, 760.
Persistence in depth: Collins, 217; Garrison, 359; Lett, 657; Maclaren, 706; Rickard, 912; Tolman, 1092.
Placer deposits: Tyrrell, 1116.
Pyrite, New York St. Lawrence Co.: Smyth, 1004.
Replacement of siliceous rock by pyrite: Turner, 1112.
Replacement ore bodies: Knox, 602; Stevens, 1031.
Secondary sulphide enrichment: Winchell, 1225.
Secondary sulphide zones: Emmons, 311.
Silver: Matteson, 727.
British Columbia, East Kootenay: Schofield, 954.
Idaho, Wardner district: Ransome, 885.
Nevada, Austin: Taylor, 1073.
Sulphur deposits: Stutzer, 1059.
Tin: Ferguson and Bateman, 322; Singewald, 987.
Turquoise, Burro Mountains, N. Mex.: Paige, 820.
Types of ore deposits: Lawson, 642.
Utah, Park City district: Boutwell, 92.
Vein quartz, St. Anthony mine: Moore, 779.
Washington, Index district: Weaver, 1168.

Ore Shoots. *See* Economic geology, *and* Ore deposits, origin.

Oregon.
General.
Bibliography: Henderson and Winstanley, 445.
Crater Lake, geological history: Diller, 282.
Economic.
Economic resources: Parks, 828.

Oregon—Continued.
Economic—Continued.
Mines and prospects, southwestern Oregon: Diller, 283.
Road materials: Parks, 827.
Stratigraphic.
Klamath region: Hershey, 452.
Southwestern Oregon: Diller, 283.
Triassic, Baker Co., section: Smith, 995.
Paleontology.
Tertiary fresh-water Mollusca: Hannibal, 427.
Oriskany sandstone of Ontario: Stauffer, 1024.
Orogeny.
General: Reid, 898, 899.
Basin-range structure: Burling, 134.
Orthoclase as a vein mineral: Rogers, 929.
Oscillation. *See* Changes of level.
Outliers.
Vermont, Ordovician outlier in Sudbury: Dale, 251.
Overlook Mountain, New York, structure and glaciation: Stevens, 1034.
Paint. *See* Mineral paints.
Paleobotany.
General: Knowlton, 601.
Alabama, Widdringtonites: Berry, 69.
Araucarioxylon type: Jeffrey, 542.
Arctic floras: Nathorst, 792.
Canada: Wilson, 1222.
Colorado, fossil fruits and flowers: Cockerell, 209.
Conifers, Cretaceous, structure: Thompson, 1082.
Cretaceous, Long Island: Hollick, 489.
Cretaceous Pityoxylon, New Jersey: Bailey, 37.
Cycadeoidea, flower buds: Wieland, 1204.
Devonian: Matthew, 730.
Gigantopteris: White, 1193.
Gymnosperms, history: Coulter, 228.
Lepidostrobus, Warren County, Iowa: Tilton, 1086.
Newfoundland, Psygmophyllum majus: Arber, 20, 21.
New Jersey, Cretaceous palm: Stevens, 1035.
Phylogeny and taxonomy: Coulter, 229.
Pityoxylon: Thomson and Allin, 1084.
Psygmophyllum majus, Newfoundland: Arber, 20.
Relations to botany: Hollick, 488.
morphology: Jeffrey, 543.
Triassic, Pennsylvania: Wherry, 1190.
Virginia, Neocalamites from Triassic: Berry, 68.
Pleistocene plants from Blue Ridge: Berry, 71.
Walnuts and hickories, geologic history: Berry, 73.
Wood, fossil, Yellowstone National Park: Platen, 863.
Paleoclimatology.
Arctic floras: Nathorst, 792.
Carboniferous: Woodworth, 1249.
Delta deposits: Barrell, 48.
Devonian climatic zones: Matthew, 730.
Paleogeographic maps.
General: Scharff, 946.
Paleogeography. *See also* Geologic history; Paleoclimatology: Paleogeographic maps.
General: Scharff, 946.
Climate and evolution: Matthew, 735.
Cambrian: Peach, 836.
Devonian: Kindle, 581; Matthew, 730.
Ordovician: Foerste, 328.
Tertiary: Osborn, 815.
Paleontology (general). *See also the classes of animals and* Paleobotany. *For stratigraphic see the different systems. For regional see the names of States.*
General: Scharff, 946.
Coloration in Gastropoda: Girty, 369.
Eryops and origin of limbs: Gregory, 401, 402, 403.
Evolution: Osborn, 808.
Footprints and tracks, formation of: Brown, 116.
Nomenclature of types: Burling, 136.
Origin of certain unit characters: Osborn, 810.
Progress in 1911: Eastman, 302.
Removing tests from fossils: Buckman, 126.
Ten years' progress in vertebrate paleontology: Bassler *et al.*, 53.
Tetraplasy: Osborn, 814.
Vertebrates, evolutionary evidences: Williston, 1213.
Paleozoic (undifferentiated).
Alaska, Bonnifield region: Capps, 170.
Iliamna region: Martin and Katz, 721.
Palladium.
United States: U. S. G. S., 1127.
Panama.
General.
Culebra cut: MacDonald, 700.
Economic.
Coal deposits: MacDonald, 699.
Dynamic and structural.
Culebra cut, heated areas: MacDonald, 697, 698; Williams, 1208.
Paleontology.
New species of fossil shells: Dall, 253.
Paragenesis of minerals.
General: Rogers, 926.
Montana, Butte district: Weed, 1171.
Pawpaw quadrangle, Maryland-West Virginia-Pennsylvania: Stose and Swartz, 1058.

Peat.
Canada: Anrep, 19.
Ohio: Dachnowski, 248.
Quebec: Denis, 278.
United States: U. S. G. S., 1127.
Virginia, Coastal Plain: Watson, 1161.
Pebbles.
Alabama, Carboniferous: Prouty, 874.
Pelecypoda. *See also* Mollusca.
Alaska, Mytilus middendorfii: Gratacap, 395.

Pennsylvania.
General.
Scranton district: Griffith and Conner, 404.
Economic.
Acme graphite mines and mills, Chester Co.: Beattie, 59.
Claysville quadrangle: Munn, 782.
Coal fields, Washington and Greene counties: Boileau, 90.
Graphite deposits: Miller, 759.
Hematite ore, Durham: Bayley, 58.
Mineral pigments: Miller, 757.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Portland cement materials, Lehigh district: Peck, 839.
Scranton region: Darton, 260.
Talc and serpentine, Northampton Co.: Peck, 839.
Dynamic and structural.
Siliceous oolites, origin: Moore, 778.
Sun-crack structure, Triassic diabase: Wherry, 1189.
Physiographic.
Claysville quadrangle: Munn, 782.
Lehigh district: Peck, 839.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Stratigraphic.
Central Pennsylvania, siliceous oolites: Ziegler, 1262.
Claysville quadrangle: Munn, 782.
Lehigh district: Peck, 839.
Newark group: Wherry, 1191.
Onondaga formation: Kindle, 581.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
South Mountain: Eaton, 303.
Triassic: Wherry, 1188.
Paleontology.
Olenopsis from Cambrian: Walcott, 1147.
Pleistocene fauna, Frankstown: Holland, 486.
Silicified wood, Triassic: Wherry, 1190.
Petrology.
Siliceous oolites: Moore, 778.
Central Pennsylvania, siliceous oolites: Ziegler, 1262.
Mineralogy.
Carnotite: Wherry, 1187.
Pennsylvanian. *See* Carboniferous.
Pentremites. *See* Blastoidea.
Peoria quadrangle, Illinois: Udden, 1117.
Permian. *See* Carboniferous.

Permian series: La Forge, 615.
Petroleum.
General.
Accumulation: Johnson, 554.
Association with faults and dikes: Clapp, 187.
Differential cementing: Johnson, 555.
Dome theory: Harris, 430; Lucas, 685.
Geology, value in petroleum industry: Hager, 416; Knapp, 591.
Geothermic gradients, relation to: Shaw, 971.
Igneous intrusions, effect on accumulation in northeastern Mexico: Garfias, 357.
Magnetic declination lines: Tarr, 1069.
Oil and gas accumulation in Appalachian region: Munn, 788.
Oil-field structure, graphic representation: Heindl, 444.
Oil literature: Breger, 105.
Origin: Blatchley, 79; Coste, 227; Latimer, 635; and geologic occurrence: Anderson, 17.
Quaquaversal structure: Clapp, 186.
Alaska, Iliamna region: Martin and Katz, 721.
Katalla field: Thompson, 1081.
Appalachian and central states: Ashley, 24.
California: Prutzman, 875; Requa, 901.
San Joaquin Valley: Anderson, 15.
Illinois: Blatchley, 79, 81, 82, 83; Wheeler, 1185.
Carlinville field: Kay, 563.
Carlyle oil field: Shaw, 970.
Crawford and Lawrence counties: Blatchley, 80.
Kentucky, Campton pool: Munn, 783.
Kenova quadrangle: Phalen, 850.
Knox Co.: Munn, 784.
Louisiana: Harris, 429; Lucas, 684; Wooton, 1251.
Mexico: Hornaday, 499; Skertchly, 989.
northeastern, accumulation: Garfias, 357.
Michigan: Allen *et al.*, 13.
New Brunswick, Moncton area: Young, 1259.
New York: Newland, 798.
Oklahoma: Gould, 385.
Ponca City field: Ohern and Garrett, 803.
Oregon: Parks, 828.
Pennsylvania, Claysville quadrangle: Munn, 782.
Tennessee: Ashley, 26.
Spring Creek field: Munn, 787.
Texas: Hornaday, 498.
Wichita and Clay counties: Udden, 1119; Udden and Phillips, 1121.
United States: U. S. G. S., 1127.

Petroleum—Continued.
Utah, Green River field: Knight, 593; Anon., 1271.
San Juan field: MacDonald, 702; Woodruff, 1243.
West Virginia, Doddridge and Harrison counties: Hennen, 447.
Wyoming, Douglas field, Converse Co.: Jamison, 539.
Muddy Creek field, Carbon Co.: Jamison, 539.
Powder River oil field: Wegemann, 1178.
Salt Creek field, Natrona Co.: Jamison, 540.
Spring Valley field: Merrill, 748.
Petrology (general). *See also* Igneous and volcanic rocks; Technique. *For regional see names of States. For rocks described see list, p. 170.*
General: Palache, 823; Watson, 1163.
Abstracts and reviews: Cross, 238; Johannsen *et al.*, 545–547.
Brun's new data on volcanism: Winchell, 1223.
Conversion of rock analyses: Mead, 739.
Crystallization, order in igneous rocks: Bowen, 96.
Foliated crystalline rocks: Trueman, 1109.
Lava, origin: Hobbs, 477.
Methods of petrographic-microscopic research: Wright, 1252.
Microscopical petrography, quantitative: Wright, 1253.
Quantitative classification, modifications of: Cross *et al.*, 240.
Rocks, average composition: Clarke, 195.
Rutile-bearing rocks: Watson, 1164.
Silicates, salic: Washington, 1157.
Symbols in quantitative classification: Cross, 239.
Texas: Lucas, 684.
Phoenix, Boundary district, British Columbia: LeRoy, 655.
Phosphate.
General: Stone, 1048.
Arkansas: Waggaman, 1141.
Florida: Sellards, 962.
Kentucky: Gardner, 356; Waggaman, 1141.
Ontario: Schmid, 950.
Quebec: Denis, 278; Schmid, 950.
Tennessee: Waggaman, 1141.
United States: Waggaman, 1142; U. S. G. S., 1127.
Physiographic (general). *For regional see names of States. See also* Drainage changes.
General: Davis, 273; Purdue, 880.
Atlantic and Pacific types of coast: Schwarz, 958.
Bolson in Southwest, development of: Meinzer, 744.
Physiographic (general)—Continued.
Coastal Plain: Crosby, 235.
Cross cutting and retrograding of stream beds: Dellenbaugh, 276.
Description of land forms: Davis, 270, 272.
Desert ranges: Paige, 819.
Laboratory work: Clem, 204.
Mississippi Valley: Hart, 431.
New terms: Cairnes, 152.
Physiographic development in arid regions: Keyes, 573.
Plateau-plains, arid region: Keyes, 579.
Relation of geography to geology: Davis, 271.
United States: Blackwelder, 76.
Pisces.
Chimæroids, Cretaceous: Hussakof, 526.
Connecticut, Triassic: Lull, 688.
Devonian, from Scaumenac Bay, Que.: Hussakof, 525.
Edestus from Iowa: Hay, 438.
Mesozoic and Cenozoic fishes: Eastman, 301.
Paleozoic: Dean, 275.
Placers. *See also* Gold.
Colorado, Breckenridge: Lakes, 619.
Pay streak: Tyrrell, 1116.
Planetable in gtologic mapping: Pelton and Irwin, 840; Ransome, 884; Wegemann, 1180.
Plants. *See* Paleobotany.
Plateau plains, origin: Keyes, 579.
Platinum.
United States: U. S. G. S., 1127.
Pleistocene. *See* Glacial geology; Quaternary.
Pliocene. *See* Tertiary.
Porcupine gold fields. *See* Ontario.
Porocystis pruniformis Cragin: Böhm, 89.
Portland Canal district, British Columbia: McConnell, 696.
Portland cement. *See* cement.
Potash.
General: Breger, 104; Stutzer, 1060.
Field investigations: Gale, 350.
American deposits: Mitchell, 768.
California, Searles Lake region: Hammon, 424, 425.
Nevada: Free, 341.
Railroad Valley: Sheldon, 973.
Texas, Spur, Dickens Co.: Udden, 1120.
United States: Gale, 349; U. S. G. S., 1127.
Utah, Marysville: Butler and Gale, 141.
Western United States: Surr, 1061.
Wyoming, Leucite Hills, Sweetwater Co.: Schultz and Cross, 957.
Powder River oil field, Wyoming: Wegemann, 1178.

Pre-Cambrian.
Stratigraphy.
General: Holmquist, 490.
Arctic regions: Bugge, 127.
British Columbia: Daly, 255, 256.
Ice River district: Allan, 10.
Shuswap lakes region: Daly, 254.
Colorado, Alma district: Patton *et al.*, 834.
Greenland, Julianehaab region: Ussing, 1130.
northwestern: Helm, 442.
Idaho, Cœur d'Alene region, Belt and Pelona series: Hershey, 452.
Iowa: Norton *et al.*, 800.
Michigan, Keweenaw series: Lane, 627.
Minnesota: Zapffe, 1260.
iron ranges: Van Barneveld, 1133.
Missouri, Ozark region: Crane, 233.
North America: Willis, 1212.
North Carolina, Dan River field: Stone, 1046.
Ontario, Cripple Creek area: Bruce, 124.
Gowganda to Porcupine area: McMillan, 709.
Lake of the Woods region: Parsons, 832.
Larder Lake district: Wilson, 1220.
McArthur township: Hopkins, 491.
northern: Moore, 780.
Onaping sheet: Collins, 218.
Patricia district: Miller *et al.*, 763.
Porcupine area: Burrows, 137.
Rainy Lake: Lawson, 637.
Steeprock Lake: Lawson, 636.
West Shiningtree district: Stewart, 1040.
Pennsylvania, Durham Hills: Peck, 839.
Lehigh region: Miller, 757.
South Mountain: Eaton, 303.
Quebec, Keekeek and Kewagama region: Bancroft, 43.
Kewagama Lake area: Wilson, 1221.
Orford area: Harvie, 433.
Ottawa valley: Stansfield, 1018.
Pontiac County: Wilson, 1220.
South Dakota, Harney Peak district: Duncan, 296.
Texas, Llano and Burnett quadrangles: Paige, 817.
Wisconsin, Lake Superior coast: Thwaites, 1085.
Paleontology.
Steeprock fauna, Ontario: Walcott, 1151.
Precious stones. *See also* Diamonds; Sapphires; Turquoise.
North Carolina, emeralds: Sterrett, 1030.
Opal in Nevada and Idaho: Kunz, 613.
United States: Sterrett, 1029; U. S. G. S., 1127.
Primates. *See* Mammalia.
Prince Edward Island.
Stratigraphic.
Permo-Carboniferous rocks: Watson, 1159.
Protopalæaster narrawayi: Hudson, 519; covering plates: Raymond, 891.
Pseudomorphs.
Stibnite, San Luis Potosi: Ford and Bradley, 338.
Pseudostratification: Louderback, 677.
Psygmophyllum majus: Arber, 21.
Pyrite.
General: Phalen, 851.
Canada: Wilson, 1217, 1218.
New York: Newland, 798.
St. Lawrence Co.: Smyth, 1004.
Texas, Llano and Burnett quadrangles: Paige, 817.
United States: U. S. G. S., 1127.
Quartz.
United States: U. S. G. S., 1127.
Quaternary. *See also* Glacial geology.
Stratigraphy.
General: Hay, 437.
Alaska: Tarr, 1063.
Bonnifield region: Capps, 170.
Iliamna region: Martin and Katz, 721.
Colorado, Alma district: Patton *et al.*, 834.
Apishapa quadrangle: Stose, 1056.
Idaho, eastern: Hershey, 451.
Illinois, Peoria quadrangle: Udden, 1117.
Indiana: Hay, 435.
Iowa: Norton *et al.*, 800.
Maryland, Choptank quadrangle: Miller, 758.
Montana, western: Hershey, 451.
New Brunswick, Bathurst district: Young, 1258.
Nicaragua, northeastern: Hershey, 450.
North Carolina, Coastal Plain: Clark *et al.*, 193.
North Dakota, Bismarck quadrangle: Leonard, 654.
Utah, Park City district: Boutwell, 92.
Vermont, Green Mountain region: Perkins, 845.
Virginia, Coastal Plain: Clark and Miller, 192.
Washington, eastern: Hershey, 451.
Yukon, Wheaton district: Cairnes, 149.
Paleontology.
Avian faunas of Pacific coast: Miller, 762.
California, Pleistocene rodents: Kellogg, 569.
Rancho La Brea fauna, Canidæ: Merriam, 745.
Carnivora: Merriam, 746.
Glyptodont from Mexico: Brown, 118, 121.
Indiana, vertebrata: Hay, 435.
Panama and Costa Rica: Dall, 253.

Quaternary—Continued.
Paleontology—Continued.
Pennsylvania, Frankstown: Holland, 486.
Pleistocene faunas: Hay, 437.
Quebec, Ostrea in Pleistocene of Montreal: Ardley, 22.
Virginia, Pleistocene plants from Blue Ridge: Berry, 71.

Quebec.
General.
Harricanaw and Nottaway rivers region: Bancroft, 42.
Economic.
Amherst graphite deposits: Cirkel, 181.
Clay resources: Ries, 915.
Gold, Meule Creek, Chaudiere district: Keele, 566.
Iron deposits north of St. Lawrence: Dulieux, 290, 291.
Keekeek and Kewagama lakes region: Bancroft, 43.
Magnetic iron sands, Natashkwan, Saguenay Co.: Mackenzie, 704.
Mica: Schmid, 951.
Mica, graphite, and apatite deposits, Ottawa Valley: Stansfield, 1018.
Mining operations in 1911: Denis, 278.
Phosphate and feldspar deposits: Schmid, 950.
Pontiac County: Wilson, 1220.
Titaniferous ores and magnetic sands, St. Lawrence: Dulieux, 292.
Dynamic and structural.
Changes of level, postglacial: Goldthwait, 378.
Physiographic.
Covey Hill region: Spencer, 1010.
Stratigraphic.
General: Valiquette, 1132.
Beloeil and Rougemont Mountains: O'Neill, 806.
Entry Island (Magdalen Islands): Clarke, 199.
Keekeek and Kewagama lakes region: Bancroft, 43.
Kewagama Lake area: Wilson, 1221.
Larder Lake district, Pontiac Co.: Wilson, 1220.
National Transcontinental Railway in southern Quebec: Dresser, 288.
Orford area: Harvie, 433.
Ottawa Valley: Stansfield, 1018.
Paleontology.
Devonic fishes from Scaumenac Bay: Hussakof, 525.
Ostrea in Pleistocene of Montreal: Ardley, 22.
Petrology.
Ilmenite rocks, St. Urbain: Warren, 1156.
Mineralogy.
Rutile and sapphirine: Warren, 1156.

Quicksilver.
United States: McCaskey, 693; U. S. G. S., 1127.

Radioactivity.
Bearings on geology: Chamberlin, 179.

Rampart region, Alaska: Eakin, 297.

Rare earths.
General: Hess, 456.
Texas, Llano: McLaren, 705.
Llano and Burnet quadrangles: Paige, 817.

Red beds, origin: Beede, 62.

Reptilia.
Alabama, Cretaceous: Gilmore, 365.
Camptosaurus: Gilmore, 366.
Chelonia: Hay, 436.
Connecticut, Triassic: Lull, 688.
Cotylosauria: Case, 175.
Cretaceous dinosaurs: Lull, 687.
Diadectes lentus and Animasaurus carinatus: Case and Williston, 177.
Dinosaurs from Alberta: Matthew, 733.
Dinosaur-turtle analogy: Wieland, 1205.
Glyptodont from Jalisco: Brown, 118.
Indiana, Pleistocene: Hay, 435.
Jurassic dinosaurs: Holland, 487.
Jurassic plesiosaurs, Wyoming: Mehl, 741.
Limnoscelis, New Mexico: Williston, 1214.
Lysorophus, limbs: Finney, 325.
Marine reptiles: Merriam, 747.
Mexico, Jalisco, Glyptodont: Brown, 118.
Muraenosaurus and Tricleidus: Mehl, 741.
Pantylus, Texas: Mehl, 740.
Primitive reptiles: Williston, 1215.
Stegosaurus: Gilmore, 367.
Stomach stones: Moodie, 774.
Ten years' progress: Case, 176.

Restorations.
Limnoscelis: Williston, 1214.
Permian reptiles: Case, 175.
Pisces (Scaumenacia): Hussakof, 525.
Stenomylus: Peterson, 848.
Titanothere: Gregory, 400.
Trachodon: Osborn, 812.
Triassic, Connecticut Valley: Lull, 688.

Rhode Island.
Stratigraphic.
Narragansett Basin: Lahee, 617.
Petrology.
Narragansett Basin: Lahee, 617.

Rhodium.
United States: U. S. G. S., 1127.

Richmond series, Batostomas: Cumings and Galloway, 245.

Rill channels: Hudson, 518.

Ringing-rock phenomena: Wherry, 1189.
Ripple marks: Kindle, 584.
Rivers.
Hudson River: Kemp, 571.
Road materials.
Florida: Sellards, *et al.*, 964.
Oregon: Parks, 827.
Rocks described. *See list, p. 170.*
Rocks, structural features.
Crescentic fractures of glacial origin: Lahee, 616.
Foliated crystalline rocks: Trueman, 1109.
Gypsum, Albert Co., N. B.: Bailey, 38.
Joint planes: Sheldon, 974.
Joining, New Albany shale, Indiana: Culbertson, 242.
Rill channels: Hudson, 518.
Siliceous oolites, origin: Moore, 778.
Stratification: McNair, 710.
Sun-crack structure, Triassic diabase: Wherry, 1189.
Ruby placer district, Alaska: Maddren, 711.
Salem limestone, southeastern Iowa: Van Tuyl, 1136.
Salmon River district, British Columbia: McConnell, 695.
Salt.
General.
Form of salt deposits: Hahn, 420.
Canada: Cole, 215.
Louisiana: Lucas, 684; Wooton, 1250.
Michigan: Allen *et al.*, 13.
New York: Newland, 798.
Texas: Lucas, 684.
United States: U. S. G. S., 1127.
Virginia, southwestern: Stose, 1057.
Sand. *See also* Glass sand; Silica.
New York: Newland, 798.
Ohio: Condit, 219.
Oregon: Parks, 828.
Pennsylvania, Scranton region: Darton, 260.
United States: Burchard, 131; U. S. G. S., 1127.
Virginia, Coastal Plain: Watson, 1161.
Sand lime brick.
Illinois: Parr and Ernest, 831.
Sandstone. *See also* Building stone.
New York: Newland, 798.
Wisconsin, Lake Superior coast: Thwaites, 1085.
San Joaquin Valley, California, geology and possible oil resources: Anderson, 15.
San Juan Mountains, Colo., glacial epochs: Atwood and Mather, 32.
San Juan oil field, Utah: Woodruff, 1243.
Santa Rito (Chino), New Mexico, geologic and structural relations: Paige, 821.
Saskatchewan.
Economic.
Clay and shale deposits: Ries and Keele, 916.
Coal fields: Denis, 277; Dowling, 286.
Sedimentation. *See also* Erosion.
Delta deposits: Barrell, 48; Grabau, 389.
Esker fans, structure: Jaggar, 537.
Marine sedimentation, character and magnitude: Clarke, 195.
Pebble deposits: Bagg, 36.
Red beds, origin: Beede, 62.
Seismology. *See also* Earthquakes.
Harvard seismographic station, third report: Woodworth, 1248.
Microseismic motion: Burbank, 128.
Microseisms caused by frost action: Burbank, 129.
Missouri, St. Louis University: Goesse and Rueppel, 376.
Seismograph at American Museum: Hovey, 508.
Seismographic bookkeeping: Wood, 1242.
Seismographs: Reid, 896.
Seismological notes: Anon., 1272.
Selenium.
United States: U. S. G. S., 1127.
Serpentine.
Pennsylvania, Northampton Co.: Peck, 839.
Texas, Llano and Burnet quadrangles: Paige, 817.
Seward Peninsula, Alaska: Smith, 999.
Shale.
Canada, western provinces: Ries and Keele, 916.
Sherbrooke formation, British Columbia: Burling, 135.
Sheridan coal field, Wyoming: Simmons, 981.
Sidney lignite fields, Dawson County, Montana: Stebinger, 1026.
Silica, forms of: Fenner, 321.
Silurian. *For Lower Silurian see* Ordovician.
Stratigraphy.
Alaska-Yukon boundary: Cairnes, 150.
Georgia, northern: Maynard, 738.
Idaho, east: Umpleby, 1123.
Illinois, Peoria quadrangle: Udden, 1117.
Wheaton quadrangle: Trowbridge, 1104.
Iowa: Norton *et al.*, 800.
Kentucky, Dix River region: Foerste, 326.
Maryland, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Missouri, Ozark region: Crane, 233.
New Brunswick, Bathurst district: Young, 1258.
southern: Ells, 307.

Silurian—Continued.
Stratigraphy—Continued.
New York: Hartnagel, 432.
North America: Willis, 1212.
Nova Scotia, Arisaig-Antigonish district: Williams, 1211.
Ohio, Columbus quadrangle: Stauffer *et al.*, 1025.
southwestern: Fuller and Clapp, 346.
Ontario, Detroit River area: Nattress, 793.
Pennsylvania, Lehigh district: Peck, 839.
Lehigh Gap: Miller, 757.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Quebec, Entry Island (Magdalen Islands): Clarke, 199.
Orford area: Harvie, 433.
West Virginia, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Paleontology.
Maine, Eastport quadrangle: Williams, 1209.
Washington County, Mollusca: Williams, 1207.
New Brunswick, southern: Ells, 307.
Silver.
General: Coghill, 214.
Genesis of silver deposits: Matteson, 727.
Geologic structure of silver districts: Matteson, 725.
Minerals of silver deposits: Matteson, 726.
Alaska, Iliamna region: Martin and Katz, 721.
Arizona, Owl Head district: Pickard, 856.
Silverbell district: Stewart, 1037.
British Columbia, East Kootenay: Schofield, 953, 954.
Nelson area: LeRoy, 656.
California, High Grade district: Stines, 1041, 1042; Storms, 1052.
Colorado, Leadville: Butler, 144.
Idaho, Cœur d'Alene region: Huston, 527.
Wardner district: Ransome, 885.
Mexico, Sierra Mojada district: Van Horn, 1135.
Sonora, Sahuaripa district: Hynes, 530.
Sonora Valley: Hafer, 415.
Tamaulipas, San Nicolás district: Wentworth, 1182.
Montana, Blue Bird mine: Winchell and Winchell, 1227.
Butte district: Weed, 1171.
Nevada, Austin: Taylor, 1073.
Mineral Hill: Toll, 1089.
Palmyra district: Cutler, 247.
Tonopah: Eakle, 298.
New Mexico, Magdalena district: Tuttle, 1113.
Silver—Continued.
Ontario, Cobalt district: Hore, 497; Tyrrell, 1115.
Quebec: Denis, 278.
United States: U. S. G. S., 1127.
Utah, Park City district: Boutwell, 92.
Union Chief and Santaquin mines: Higgins, 461.
Yukon, Wheaton district: Cairnes, 149.
Silverbell mining district, Arizona: Stewart, 1037.
Sink holes.
Indiana, southern: Cumings, 244.
Skagit Valley, Yale district, British Columbia: Camsell, 164.
Slate.
United States: U. S. G. S., 1127.
Vermont: Perkins, 845, 846.
Soapstone.
United States: U. S. G. S., 1127.
Vermont: Perkins, 846.
Soils.
Florida: Sellards, 961.
Indiana, Greene Co.: Tharp and Mann, 1074.
Hancock, Johnson, and Shelby counties: Hole, 484.
Laporte, St. Joseph, and Bartholomew counties: Quinn, 882.
Marion Co.: Geib and Schroeder, 360.
Morgan and Owen counties: Edmonson, 306; Shannon, 965.
Posey Co.: Marean, 717.
Spencer, Warrick, and Scott counties: Mangum and Neill, 716.
Kentucky, Hartford quadrangle: Jones, 560.
Tennessee, Robertson Co.: Rogers, 930.
United States: Whitney *et al.*, 1201.
South Carolina.
Paleontology.
Echinids, Tertiary: Stefanini, 1028.
South Dakota.
General.
Black Hills, volcanic deposits: Darton, 265.
Mellette, Washabaugh, Bennett, and Todd counties: Perisho and Visher, 843.
Economic.
Lithia deposits, Black Hills: Anderson, 14.
Tin in the Black Hills: Alder, 7.
Physiographic.
Pre-Wisconsin: Todd, 1088.
Stratigraphic.
Black Hills region: Stone, 1045.
Pleistocene formations: Shimek, 977.
Sioux Falls: Shimek, 976.
Pre-Cambrian of Harney Peak district: Duncan, 296.
Spongida.
Steeprock fauna, Ontario: Walcott, 1151.
Steeprock fauna: Walcott, 1153.

Stone. *See also* Building stone.
Canada: Parks, 830.
New York: Newland, 798.
Oregon: Parks, 828.
Stratification.
General: Willis, 1212.
Pseudostratification, Santa Barbara Co., Cal.: Louderback, 677.
Stratigraphic (general). *For regional, see names of States. See also the different systems.*
General: Willis, 1212.
Coastal Plain: Crosby, 235.
Dynamic relations and terminology of stratigraphic conformity and unconformity: Crosby, 235.
Ulrich's Revision of Paleozoic systems: Hahn, 422.
United States: Blackwelder, 76.
Correlation.
Bedford shale: Girty, 370.
Carboniferous of Iowa and Missouri: Keyes, 578.
Chattanooga shale: Kindle, 582.
Coal beds, Rocky Mountain region: Lee, 649.
Coastal Plain formations: Clark and Miller, 192; Clark *et al.*, 193.
Devonian, New York and New Jersey: Clarke, 198.
Monument Creek group, Colorado: Richardson, 908.
Ohio, northeastern: Prosser, 872.
Silurian, Maine: Williams, 1209.
Tertiary: Osborn, 815.
Judith River formation: Peale, 837.
Trias: Wherry, 1191.
Virginia, Coastal Plain formations: Clark and Miller, 192.
Tables of geologic formations.
Alaska, Iliamna region: Martin and Katz, 721.
British Columbia, Boundary district: LeRoy, 655.
Ice River district: Allan, 10.
Vancouver Island: Clapp, 182.
Chattanoogan series: Ulrich, 1122.
Cincinnatian: Foerste, 328.
Colorado, Grand Mesa and West Elk Mountains fields: Lee, 647.
Devonian, Allegheny region: Kindle, 581.
Georgia, Appalachian Valley and Cumberland Plateau: Maynard, 738.
Iowa: Keyes, 577; Norton *et al.*, 800.
Kentucky, Dix River region: Foerste, 326.
Maryland: Md. G. S., 724.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Missouri: Crane, 233.
Montana, Baker field, Custer Co.: Bowen, 93.
Culbertson field, Valley Co.: Beekly, 63.
Custer Co., Terry lignite field: Herald, 448.
Stratigraphic (general)—Continued.
Tables of geologic formations—Continued.
Montana—Continued.
Dawson Co., Glendive field: Hance, 426.
eastern: Calvert, 157.
Livingston and Trail Creek fields: Calvert, 158.
Milk River field: Pepperberg, 842.
Sidney field, Dawson Co.: Stebinger, 1026.
New Mexico coal fields: Lee, 648.
Ohio, Columbus quadrangle: Stauffer *et al.*, 1025.
northeastern: Prosser, 872.
Ontario, pre-Cambrian: Moore, 780.
Ordovician of Cincinnati area: Foerste, 327.
Pennsylvania, Lehigh region: Miller, 757.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Triassic: Wherry, 1191.
Pre-Cambrian, Canada: Moore, 780.
Quebec, southern: Dresser, 288.
South Dakota: Perisho and Visher, 843.
Tennessee, eastern: Jarvis, 541.
Tennessee Valley, central part: Gordon and Jarvis, 383.
Texas, Llano and Burnet quadrangles: Paige, 817.
Utah, San Juan oil field: Woodruff, 1243.
Wasatch Co., Blacktail Mountain coal field: Lupton, 690.
Virginia, Coastal Plain: Clark and Miller, 192.
West Virginia, Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Wisconsin: Hotchkiss and Thwaites, 501.
Wyoming, Douglas oil field, Converse Co.: Jamison, 539.
Muddy Creek oil field, Carbon Co.: Jamison, 539.
Powder River oil field: Wegemann, 1178.
Wind River region: Woodruff and Winchester, 1246.
Stromatoporoids: Kirkpatrick, 588, 589.
Strontium.
United States: U. S. G. S., 1127.
Study and teaching. *See* Educational.
Subsidence. *See* Changes of level.
Subterranean water. *See* Underground water.
Sudbury nickel district, Ontario: Thomas, 1080.
Sulphur.
General: Phalen, 851.
Genesis: Stutzer, 1059.
Louisiana: Lucas, 684.
Quebec: Denis, 278.
Texas: Lucas, 684.
Culberson Co.: Phillips, 854.
United States: U. S. G. S., 1127.

Surveys.
California: Storms, 1055.
Illinois: DeWolf, 280.
Iowa: Arey, 23; Kay, 562.
Mississippi, biennial report: Miss. G. S., 767.
New Jersey, report State geologist: Kümmel, 611.
State geological surveys: DeWolf, 281.
Tennessee: Glenn, 373.
United States Geological Survey, policy: Smith, 993.
Report 1911–1912: Smith, 992.
Sussex coal field, Johnson, Natrona, and Converse counties, Wyoming: Wegemann, 1179.
Swastika gold area: Bruce, 123.
Sweetland Creek shale, Illinois: Udden, 1118.
Tables of geologic formations. *See* Stratigraphic.
Taconic question: Keith, 568.
Talc.
New York: Newland, 798.
Pennsylvania, Northampton Co.: Peck, 839.
Texas, Llano and Burnet quadrangles: Paige, 817.
United States: U. S. G. S., 1127.
Vermont: Perkins, 846.
Tantalum.
United States: U. S. G. S., 1127.
Technique.
Color scheme for crystal models: Chadwick, 178.
Geological short-cuts: Mead, 739.
Granularity limits in petrographic microscopic work: Wright, 1254.
Optic angle of gypsum: Kraus and Youngs, 609.
Optical properties of minerals, determination of: Wright, 1253.
Petrographic-microscopic methods: Wright, 1252.
Planetable in geologic mapping: Pelton and Irwin, 840; Ransome, 884; Wegemann, 1180.
Refraction, index: Lane, 632.
Removing tests from fossils: Buckman, 126.
Rock analyses, conversion of: Mead, 739.
Seismograph at American Museum: Hovey, 508.
Seismographic bookkeeping: Wood, 1242.
Seismographs: Reid, 896.
Tennessee.
General: Glenn, 373.
Report Geological Survey, 1912: Purdue, 877.
Robertson Co.: Rogers, 930.
Economic.
Aluminum and bauxite mining: Ashley, 28.
Barite deposits, Sweetwater district: Henegar, 446.
Tennessee—Continued.
Economic—Continued.
Bauxite mining: Ashley, 27.
Cave marble (cave onyx): Gordon, 380.
Clays of Henry Co.: Kirkpatrick and Nelson, 587.
Clinton iron-ore deposits: Whinery, 1192.
Iron deposits, Tuckahoe district: Gordon and Jarvis, 383.
East Tennessee: Jarvis, 541.
Lead: Nelson, 794.
Lignite and lignitic clay: Nelson, 795.
Oil and gas: Ashley, 26.
Onyx deposits: Gordon, 381, 382.
Phosphates: Waggaman, 1141.
Spring Creek oil field: Munn, 787.
Zinc deposits, northeastern Tennessee: Purdue, 878.
northern Tennessee: Purdue, 879.
Dynamic and structural.
Monteagle cave, Grundy Co.: Nelson, 796.
Stratigraphic.
Chattanoogan series: Ulrich, 1122.
Memphis: Munn, 786.
Terraces. *See also* Beaches; Shore lines.
California: Wittich, 1233.
Idaho, northern: Hershey, 451.
Indiana, Whitewater River: Hole, 483.
Mexico, Lower California: Wittich, 1233.
New Brunswick: Goldthwait, 378.
Quebec: Goldthwait, 378.
Tertiary.
General.
Correlation and paleogeography: Osborn, 815.
Stratigraphy.
Alaska, Bonnifield region: Capps, 170.
Gulkana-Susitna region: Moffit, 769.
Iliamna region: Martin and Katz, 721.
Matanuska Valley: Martin and Katz, 722.
Yentna district: Capps, 171.
British Columbia, Boundary district: LeRoy, 655.
Vancouver Island: Clapp, 182.
West Kootenay: Drysdale, 289.
California, Coalinga oil field region: Dumble, 293.
Kirker Pass Neocene section: Clark, 188.
Miocene: Smith, 996.
Monterey series: Martin, 718.
San Joaquin Valley: Anderson, 15.
Colorado, Apishapa quadrangle: Stose, 1056.
Florissant, Miocene: Cockerell, 208.
Grand Mesa and West Elk Mountains: Lee, 647.
Monument Creek group: Richardson, 908.
Costa Rica: Romanes, 931.
Peninsula of Nicoya: Romanes, 932.
Greenland, western: Heim, 443.

Tertiary—Continued.
Stratigraphy—Continued.
Idaho, northern: Hershey, 451.
Illinois, Peoria quadrangle: Udden, 1117.
Judith River formation: Peale, 837.
Kansas: Parker, 826.
Maryland, Choptank quadrangle: Miller, 758.
Mexico, eastern: Dumble, 294.
Sonora, Cananea district: Lee, 645.
Missouri, Ozark region: Crane, 233.
Montana, Culbertson field, Valley Co.: Beekly, 63.
Custer Co., Terry lignite field: Herald, 448.
eastern: Calvert, 157.
Milk River field: Pepperberg, 842.
northern: Hershey, 451.
Nevada, Elko Co.: Schrader, 955.
New Mexico, north central: Lee, 648.
Nicaragua, northeastern: Hershey, 450.
North America: Willis, 1212.
North Carolina, Coastal Plain: Clark *et al.*, 193.
North Dakota, Bismarck quadrangle: Leonard, 654.
Fort Berthold Indian Reservation: Pishel, 861.
South Dakota, south central: Perisho and Visher, 843.
Trinidad, Caroni series, Savaneta: Guppy, 414.
Uinta formations: Riggs, 917.
Utah, eastern: Umpleby, 1125.
Uinta Co., Deep Creek district: Lupton, 689.
Wasatch Co., Blacktail Mountain coal field: Lupton, 690.
Vermont, Green Mountain region: Perkins, 845.
Virginia, Coastal Plain: Clark and Miller, 192.
Washington, eastern: Hershey, 451.
King County: Evans, 313.
western: Weaver, 1169.
West Indies: Guppy, 411.
Wyoming, Bighorn basin: Sinclair and Granger, 985.
Douglas oil field, Converse Co.: Jamison, 539.
Little Powder River field: Davis, 269.
Lost Spring coal field: Winchester, 1231.
Muddy Creek oil field, Carbon Co.: Jamison, 539.
Sussex coal field: Wegemann, 1179.
Wind River region: Woodruff and Winchester, 1246.
Yukon, Wheaton district: Cairnes, 149.
Paleontology.
California, Miocene invertebrates: Smith, 996.
Monterey series: Martin, 718.
Pliocene and Pleistocene Foraminifera: Bagg, 35.

Tertiary—Continued.
Paleontology—Continued.
Californian province, fresh-water Mollusca: Hannibal, 427.
Colorado, Florissant, Coleoptera: Wickham, 1202, 1203.
Raphidia: Cockrell, 211.
Tertiary fungus gnat: Johannsen, 548.
Costa Rica: Romanes, 931.
Echinids: Stefanini, 1028.
Maryland, Miocene, Delphinodon: True, 1105.
Mollusca from the West: Cockerell and Henderson, 213.
Nebraska, rhinoceros from Miocene: Cook, 222, 223, 225.
Sioux County: Cook, 224.
North Carolina, Coastal Plain: Clark *et al.*, 193.
Titanotheres, Uinta formations: Riggs, 917.
Trinidad: Maury, 736, 737.
Springvale, Miocene fossils: Guppy, 409, 410.
Vermont, Green Mountain region: Perkins, 845.
Virginia, Coastal Plain: Clark and Miller, 192.
Washington, western: Weaver, 1169.
Tetraplasy: Osborn, 814.
Texas.
General.
Potash, Permian rocks: Udden, 1120.
Salines as geologic thermometer: Lachmann, 614.
Southwest Texas: Madison, 713.
Economic.
Dome theory: Lucas, 685.
Gold and rare metals, Llano: McLaren, 705.
Gold in Eocene deposits: Dumble, 295.
Llano and Burnett quadrangles: Paige, 817.
Oil and gas fields, Wichita and Clay Counties: Udden, 1119; Udden and Phillips, 1121.
Oil fields: Hornaday, 498.
Sulphur, Culberson Co.: Phillips, 854.
Sulphur and sulphur oil deposits of Coastal Plain: Lucas, 684.
Physiographic.
Llano and Burnett quadrangles: Paige, 817.
Stratigraphic.
Llano and Burnett quadrangles: Paige, 817.
Oil and gas fields, Wichita and Clay Counties: Udden and Phillips, 1121.
Paleontology.
Cockroaches: Cockerell, 212.
Cotylosauria: Case, 175.
Diplocaulia: Moodie, 773.
Diplocaulus: Huene, 521.
Eryops: Huene, 520.
Mesozoic flora: Berry, 70.

Texas—Continued.
Paleontology—Continued.
Pantylus cordatus: Mehl, 740.
Porocystis pruniformis: Böhm, 89.
Petrology.
Llano and Burnett quadrangles: Paige, 817.
Underground water.
Southwest Texas: Madison, 713.
Textbooks.
Dana's Manual of mineralogy: Ford, 335.
Erklärende Beschreibung der Landformen: Davis, 270.
Examination of prospects: Gunther, 408.
Guide to minerals: Gratacap, 394.
Mineralogy: Phillips, 852; Rogers, 921.
Practical field geology: Farrell, 319.
Syllabus of historical geology: Grabau, 388.
United States, geology: Blackwelder, 76.
Tin.
General.
Genetic relations: Singewald, 987.
Geologic features: Ferguson and Bateman, 322.
Alaska, Seward Peninsula: Smith, 999.
New Brunswick: Brock, 108.
Nova Scotia: Piers, 858.
South Dakota, Black Hills: Alder, 7.
United States: U. S. G. S., 1127.
Titanium. *See also* Rutile.
United States: U. S. G. S., 1127.
Titanotheres from the Uinta formations: Riggs, 917.
Topaz.
New Brunswick: Brock, 108.
Trachodon: Osborn, 812.
Trail Creek coal field, Montana: Calvert, 158.
Triassic.
Stratigraphy.
Alaska: Martin, 720.
Gulkana-Susitna region: Moffit, 769.
Iliamna region: Martin and Katz, 721.
Porcupine to Arctic boundary: Maddren, 712.
southeastern: Atwood, 29.
Alberta, Roche Miette area: Dowling, 285.
British Columbia, Vancouver Island: Clapp, 182.
Connecticut: Lull, 688.
Coral reefs: Smith, 995.
New Mexico, northern: Williston and Case, 1216.
North America: Willis, 1212.
North Carolina, Dan River field: Stone, 1046.
Pennsylvania: Wherry, 1188.
eastern, sun-crack structure: Wherry, 1189.
Newark group: Wherry, 1191.
South Mountain: Eaton, 303.
Triassic—Continued.
Stratigraphy—Continued.
South Dakota, Black Hills: Stone, 1045.
Utah, Park City district: Boutwell, 92.
San Juan oil field: Woodruff, 1243.
Virginia, Richmond coal field: Berry, 72.
Wyoming, Black Hills: Stone, 1045.
Douglas oil field, Converse Co.: Jamison, 539.
Yukon, Porcupine to Arctic boundary: Maddren, 712.
Paleontology.
Alaska, southeastern: Atwood, 29.
Arctic regions, Eureka Sound: Kittl, 590.
Connecticut: Lull, 688.
Coral reefs: Smith, 995.
Distribution, lower Triassic faunas: Smith, 994.
Pennsylvania: Wherry, 1191.
silicified wood: Wherry, 1190.
Utah, Park City district: Boutwell, 92.
Virginia, Neocalamites from Richmond coal field: Berry, 68.
Trilobites. *See also* Crustacea.
Asaphidæ: Raymond, 889.
British Columbia, Cambrian: Walcott, 1145.
Ordovician: Walcott, 1146.
Cambrian: Walcott, 1144.
Olenopsis, Cambrian: Walcott, 1147.
Ontario, Ottawa: Narraway, 790.
Trinidad.
General: Guppy, 411, 413.
Economic.
Asphalts: Richardson, 907.
Dynamic and structural.
New island, formation of: Anderson, 16; Bosworth, 91.
Stratigraphic.
Caroni series, Savaneta: Guppy, 414.
Paleontology.
Caroni series, Savaneta: Guppy, 414.
Eocene Mollusca: Maury, 736, 737.
Springvale fossils: Guppy, 409, 410.
Tungsten.
General.
Occurrence: Morris, 781.
Colorado, Boulder Co.: Greenawalt, 396.
New Mexico, Burro Mountains: Paige, 820.
Nova Scotia: McCallum, 692.
United States: U. S. G. S., 1127.
Tuolumne Table Mountain: Locke, 675.
Turtles. *See* Reptilia.
Types, nomenclature: Burling, 136.
Tyrannosaurus: Osborn, 811.
Unconformities.
Chattanooga shale, base in Kentucky: Kindle, 582.
Dynamic relations and terminology: Crosby, 235.
Iowa: Devonian-Carboniferous: Keyes, 578.

Unconformities—Continued.
Ohio, Bedford-Berea disconformity: Prosser, 871.
Quebec, Gaspe County: Clarke, 199.
Silurian-Devonian, Ontario: Stauffer, 1024.
Underground water (general). *See also* Geysers; Mineral waters; Springs; Thermal waters. *For regional see names of States.*
Domestic water supplies for the farm: Fuller, 345.
Upper Silurian. *See* Silurian.
Uranium.
United States: U. S. G. S., 1127.
Utah.
General.
Marsh gas, near Moab: Woodruff, 1244.
Economic.
Alunite near Marysville: Butler and Gale, 141.
Blacktail Mountain coal field, Wasatch Co.: Lupton, 690.
Deep Creek district, Vernal coal field, Uinta Co.: Lupton, 689.
Green River oil field: Knight, 593; Anon., 1271.
Nitrate deposits: Gale, 348.
Park City district: Boutwell, 92.
San Juan oil field: MacDonald, 702; Woodruff, 1243.
Union Chief and Santaquin mines: Higgins, 461.
Dynamic and structural.
Bannock overthrust: Richards and Mansfield, 903.
Basin-range structure, Cricket Range: Burling, 134.
Physiographic.
Peneplain, Tertiary: Umpleby, 1125.
Stratigraphic.
Blacktail Mountain coal field, Wasatch Co.: Lupton, 690.
Deep Creek district, Uinta Co.: Lupton, 689.
Park City district: Boutwell, 92.
San Juan oil field: Woodruff, 1243.
San Rafael Swell: Lupton, 691.
Shinarump section: Lawson, 640.
Tushar Range, geology: Butler and Gale, 141.
Uinta formations: Riggs, 917.
Paleontology.
Eocene titanotheroid from Uinta basin: Gregory, 399.
Tertiary fresh-water Mollusca: Hannibal, 427.
Titanotheres, Uinta formations: Riggs, 917.
Mineralogy.
Aluminum arsenate: Clarke, 197.
Beaver Co.: Schaller, 936.
Selenite crystals: Talmage, 1062.
Variscite: Schaller, 940, 941.
Utah—Continued.
Underground water.
Ground water, Juab, Millard, and Iron counties: Meinzer, 742.
Valdez gold-mining district, Alaska: Storm, 1050.
Valleys.
General: Tyrrell, 1116.
Origin: Purdue, 880.
Yosemite and Hetch Hetchy valleys: Matthes, 728.
Vanadium.
General: Watson, 1163.
Colorado, southwestern: Thomas, 1078.
United States: U. S. G. S., 1127.
Vermont.
General.
Report State geologist, 1911–1912: Perkins, 844.
Economic.
Marbles of western Vermont: Dale, 250.
Mineral resources: Perkins, 846.
Green Mountain region: Perkins, 845.
Stratigraphic.
Albany terranes: Richardson and Collister, 905.
Craftsbury terranes: Richardson, 904.
Green Mountain region: Perkins, 845.
Irasburg: Richardson and Conway, 906.
Ordovician outlier in Sudbury: Dale, 251.
Vernal coal fields, Uinta Co., Utah: Lupton, 689.
Vertebrata (general). *See also* Amphibia; Aves; Mammalia; Pisces; Reptilia.
General: Sinclair, 982.
Canada: Lambe, 626.
Eryops and origin of limbs: Gregory, 401, 402, 403.
Evolutionary evidences: Williston, 1213.
Nebraska, Sioux County: Cook, 224.
Permian: Hay, 439.
Ten years' progress in vertebrate paleontology: Bassler *et al.*, 53.
Virginia.
General.
Report State geologist, 1910–1911: Watson, 1160.
Economic.
Coastal Plain: Watson, 1161.
Salt and gypsum deposits, southwestern Virginia: Stose, 1057.
Zirconiferous sandstone, Ashland: Watson and Hess, 1165.
Physiographic.
Coastal Plain: Clark and Miller, 192.
New River district, Mississippian delta: Branson, 103.
Stratigraphic.
Coastal Plain geology: Berry, 67; Clark and Miller, 192.
Mississippian delta: Branson, 103.

Virginia—Continued.
Stratigraphic—Continued.
Onondago formation: Kindle, 581.
Richmond coal field shales, age: Berry, 72.
Paleontology.
Neocalamites from Richmond Triassic: Berry, 68.
Pleistocene plants from Blue Ridge: Berry, 71.
Mineralogy.
Turquoise, crystallized: Schaller, 936, 938.
Volcanic ash.
Alaska, Kodiak: Fry, 342.
Seward Peninsula: Smith, 1000.
Volcanic rocks. *See* Igneous and volcanic rocks.
Volcanism.
Brun's new data: Winchell, 1223.
Volcanoes.
Alaska, Katmai eruption: Clark, 189; Dailey, 249; Anon., 1273.
Costa Rica, Reventado: Tristán, 1101.
Eruptions, 1911: Reid, 894.
Hawaii: Jaggar, 538; Komorowicz, 606.
Kilauea: Penck, 841.
Volcanic craters and explosions: Anderson, 18.
Volcanoes, extinct.
New Mexico, northeastern: Lee, 650.
Wardner district, genesis of lead-silver ores: Ransome, 885.
Washington.
General.
St. Helens mining district: Zapffe, 1261.
Economic.
Coal fields of King County: Evans, 313.
Index mining district: Weaver, 1168.
Nickel in San Poil district: Bancroft, 44.
Roslyn coal field: Daniels, 259.
St. Helens mining district: Winchell, 1226.
Dynamic and structural.
Glaciers of Mt. Rainier: Matthes, 729.
Physiographic.
Eastern Washington: Hershey, 449, 451.
Stratigraphic.
Index mining district: Weaver, 1168.
King County: Evans, 313.
Tertiary, western Washington: Weaver, 1169.
Paleontology.
Tertiary, freshwater Mollusca: Hannibal, 427.
western Washington: Weaver, 1169.
Petrology.
St. Helens mining district: Zapffe, 1261.
Mineralogy.
Ferritungstite: Schaller, 936, 937.

Water, underground. *See* Underground water.
Well records. *See* Borings.
West Indies (general). *See also names of islands.*
General: Wall, 1155.
West Kootenay, British Columbia: Drysdale, 289.
West Shiningtree gold district: Stewart, 1040.
West Virginia.
Economic.
Doddridge and Harrison counties: Hennen, 447.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Southern part of West Virginia: Parsons, 833.
Physiographic.
Doddridge and Harrison counties: Hennen, 447.
Kenova quadrangle: Phalen, 850.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Stratigraphic.
Doddridge and Harrison counties: Hennen, 447.
Kenova quadrangle: Phalen, 850.
Onondaga formation: Kindle, 581.
Pawpaw and Hancock quadrangles: Stose and Swartz, 1058.
Red beds: Beede, 62.
Paleontology.
Ames limestone fossils: Beede, 61.
Wheaton district, Yukon: Cairnes, 149.
Wheaton quadrangle, Illinois: Trowbridge, 1104.
Wind River region, Fremont and Natrona counties, Wyoming: Woodruff and Winchester, 1246.
Wind work.
Peneplanation in arid regions: Keyes, 573.
Plateau plains: Keyes, 574, 579.
Wisconsin.
General.
Report of Survey: Birge, 74.
Economic.
Zinc deposit, new type: Cox, 230.
Physiographic.
Sandstones, Lake Superior coast: Thwaites, 1085.
Stratigraphic.
Green Lake County: Alden, 6.
Sandstones, Lake Superior coast: Thwaites, 1085.
Wolframite. *See* Tungsten.
Worcester phyllite, age: White, 1194.
Wyoming.
General.
Glacial deposits east of Cody: Sinclair, 984.
Yellowstone National Park, geological history: Hague, 417.

Wyoming—Continued.
Economic.
Black Hills region: Stone, 1045.
Cambria coal field: Simmons, 980.
Douglas oil field, Converse Co.: Jamison, 539.
Little Powder River coal field: Davis, 269.
Lost Spring coal field, Converse Co.: Winchester, 1231.
Muddy Creek oil field, Carbon Co.: Jamison, 539.
Nitrate deposits: Gale, 348.
Potash-bearing rocks, Leucite Hills, Sweetwater Co.: Schultz and Cross, 957.
Powder River oil field: Wegemann, 1178.
Salt Creek oil field, Natrona Co.: Jamison, 540.
Sheridan coal field: Simmons, 981.
Spring Valley oil field: Merrill, 748.
Sussex coal field, Johnson, Natrona, and Converse counties: Wegemann, 1179.
Wind River region coal fields, Fremont and Natrona counties: Woodruff and Winchester, 1246.
Dynamic and structural.
Gros Ventre slide: Blackwelder, 78.
Yellowstone National Park, silica and lime deposition: Darton, 262.
Physiographic.
Cenozoic history of central Wyoming: Baker, 40.
Cody region: Sinclair, 983.
Natural bridges in eastern Wyoming: Barnett, 46.
Wind River Mountains: Westgate and Branson, 1184.
Stratigraphic.
Bighorn basin: Sinclair and Granger, 985.
Black Hills region: Stone, 1045.
Cody region: Sinclair, 983.
Douglas oil field, Converse Co.: Jamison, 539.
Little Powder River Coal field: Davis, 269.
Lost Spring coal field, Converse Co.: Winchester, 1231.
Muddy Creek oil field, Carbon Co.: Jamison, 539.
Powder River oil field: Wegemann, 1178.
Salt Creek oil field, Natrona Co.: Jamison, 540.
Sussex coal field, Johnson, Natrona, and Converse counties: Wegemann, 1179.

Wyoming—Continued.
Stratigraphic—Continued.
Wind River region coal fields, Fremont and Natrona counties: Woodruff and Winchester, 1246.
Paleontology.
Jurassic frog: Moodie, 776.
Jurassic plesiosaurs: Mehl, 741.
Trachodon integument: Osborn, 812.
Wood, fossil, Yellowstone National Park: Platen, 863.
Mineralogy.
Lorandite, Rambler mine: Rogers, 923.
Sheridan County: Wolff, 1237.
Yellowstone National Park.
Geological history: Hague, 417.
Geysers: Weed, 1172.
Silica and lime deposition: Darton, 262.
Yentna district, gold placers: Capps, 171.
Yosemite Valley: Matthes, 728.
Yucatan: Huntington, 524.
Yukon.
General.
Geology of boundary between Porcupine and Yukon rivers: Cairnes, 150.
Economic.
Coal fields: Denis, 277.
Klondike district: Cairnes, 151.
Ore and coal-bearing formation: Cairnes, 155.
Placer deposits: Tyrrell, 1116.
Wheaton district: Cairnes, 149.
Physiographic.
Differential erosion and equiplanation: Cairnes, 153.
Stratigraphic.
Orange group: Cairnes, 154.
Wheaton district: Cairnes, 149.
Zinc.
Colorado, Leadville: Butler, 144.
Montana, Butte district: Weed, 1171.
New Mexico, Magdalena district: Tuttle, 1113.
New York: Newland, 798.
Oklahoma, Miami district: Chapman, 180.
northeastern: Snider, 1005.
Quebec: Denis, 278.
Tennessee, northeastern: Purdue, 878.
northern: Purdue, 879.
United States: U. S. G. S., 1127.
Utah, Park City district: Boutwell, 92.
Wisconsin: Cox, 230.
Zircon.
United States: U. S. G. S., 1127.
Virginia, Ashland: Watson and Hess, 1165.

LISTS.

CHEMICAL ANALYSES.

[The numbers refer to entries in this bibliography.]

Abrasives, 1127.
Adamellite, 127.
Akerite, 51.
Alaskite, 680.
Albite diorite, 594.
Aluminum arsenate, 197.
Alunite, 141.
Analcite, 331.
Andesite, 51, 92, 1224.
Apatite, 925.
Aplite, 127, 680, 1171.
Apophyllite, 627.
Asphalt, 1127.
Auganite, 1224.
Augite porphyrite, 655.
Augite trachyte, 655.
Barytes, 1127.
Basalt, 1224.
Bauxite, 1127.
Beaverite, 926.
Carnotite, 1187.
Carphosiderite, 936.
Cassiterite, 936.
Cement, 1127.
Cement materials, 84.
Cement rock, 839.
Chert, 1260.
Chlorastrolite, 627.
Chlorite, 627, 1237.
Clay, 84, 447, 850, 916, 1161.
Coal, 158, 159, 231, 232, 269, 277, 284, 285, 313, 330, 371, 447, 479, 480, 690, 714, 715, 756, 842, 850, 1045, 1046, 1058, 1128, 1179, 1231, 1245.
Collophanite, 925, 936.
Cordierite magnetite, 1260.
Cordierite norite, 1260.
Covellite, 1171.
Cyanite, 1166.
Dahllite, 925, 936.
Diatomaceous earth, 1161.
Diabase, 127, 627.
Diabase porphyrite, 627.
Diallage, 627.
Diorite, 127, 1171.
Dolomite, 738.
Enargite, 1171.
Feldspar porphyry, 123.
Felsite, 627.
Ferritungstite, 936, 937.
Francolite, 925, 936.
Fuller's earth, 102.
Gabbro, 544, 627.
Gabbro aplite, 627.
Garnet, 1037.
Glass sand, 1127.
Gneiss, 839, 1166.
Granite, 51, 536, 680, 1171.
Greenalite, 1260.
Guano, 348.
Hinsdalite, 634, 936.
Hypersthene quartz diorite, 127.
Igneous rocks, average, 195.
Ilmenite, 1163.
Ilmenorutile, 936.
Iron ore, 58, 233, 290, 323, 541, 544, 643, 683, 817, 850, 988.
Kaolin, 915.
Keratophyre, 51.
Kersantite, 127.
Kinzigite, 680.
Labradorite, 627.
Lazulite, 1166.
Leonhardite, 627.
Leucite-bearing rocks, 957.
Leucitite, 957.
Lignite, 63, 654, 795, 861.
Lime, 1127.
Limestone, 84, 182, 738, 839, 1016, 1121.
Limonite, 323, 1171.
Liparose, 51.
Madupite, 957.
Magnetic sand, 291.
Magnesite, 1127.
Magnetite, 627.
Manganese, 1127.
Manganese ore, 817.
Marble, 182, 738.
Mariposose, 51.
Marl (greensand), 1161.
Marl (shell), 1161.
Melaphyr, 627.
Meteorites, 510, 750.
Mineral waters, 1127.
Monzonite, 1016, 1171.
Natramblygonite, 936.
Natural gas, 786, 1127.
Nepheline, 942.
Nephelite, 332.
Neponsetose, 51.

CHEMICAL ANALYSES—Continued.

Niter, 348.
Norite, 127.
Ocher, 757.
Olivine, 627.
Ophite, 627.
Orendite, 957.
Paint ore, 757.
Palaite, 939.
Peat, 1161.
Perthite, 1260.
Petroleum, 1127, 1178.
Phosphate rock, 925.
Plagioclase, 627.
Plumbojarosite, 936.
Podolite, 925, 936.
Porphyrite, 127.
Porphyry, 1166.
Potash, 1127.
Pyromorphite, 925.
Pyrophyllite, 1166.
Pseudomorph, 338.
Quartz diorite, 92, 655.
Quartz diorite porphyry, 92.
Quartz porphyry, 137, 627.
Quercyite, 936.
Rhyolite, 51, 1171.
Rhyolite porphyry, 1171.
Rutile, 1163, 1166.
Rutile minerals, 936.
Salmonsite, 939.
Sand, 1127, 1161.
Sandstone, 627, 871, 1085.
Sapphirine, 1156.
Schist, 1166.
Sedimentary rocks, average, 195.
Seladonite, 604.
Serpentine, 323, 839.
Shale, 84, 738, 916, 1145.
Sheridanite, 1237.
Shoshonose, 51.
Sicklerite, 939.
Slate, 757.
Spherulite, 627.
Stewartite, 939.
Strüverite, 936.
Syenite, 127, 655.
Taconite, 1260.
Tetrahedrite, 92.
Thaumasite, 936.
Tourmaline, 944.
Troctolyte, 627.
Tuff, 645.
Turquoise, 936, 938.
Umptekose, 51.
Variscite, 936, 940.
Voelckerite, 925.
Water, 193, 346, 571, 1117.
Water, mineral, 570.
Windsorite, 127.
Wollastonite, 627.
Wyomite, 957.
Zinc, 1127.

[The following list is additional to that given on p. 144 of Bulletin 524. The numbers refer to entries in that bulletin.]

Aegirite, 1166.
Albitite, 894.
Alunogen, 374.
Amphibole, 374.
Anatase, 894.
Apatite, 374.
Aplitic soda granite, 517.
Apophyllite, 374.
Barite ore, 1165.
Beaverite, 178, 179.
Beryl, 374.
Biotite, 374, 889.
Bismuth ocher, 976.
Calamine, 374.
Camptonite, 546.
Carphosiderite, 988.
Cement, 433, 437.
Chabazite, 374.
Chalk, 430.
Chrome mica, 317.
Clay, 309, 374, 439, 943, 1036.
Coal, 181, 199, 201, 202, 203, 286, 341, 486, 730, 859, 865, 1012, 1026, 1033, 1184.
Copper ore, 1182, 1216.
Corundum syenite, 949.
Covellite, 947.
Cuprodescloizite, 456.
Cyanite, 374.
Datolite, 1232.
Deweylite, 374.
Diabase, 517, 1132.
Diatom deposit, 309.
Dolomite, 184.
Eglestonite, 948.
Epidote, 374.
Epsomite, 374.
Essexite, 546.
Ferritungstite, 977.
Fluorspar, 168, 312.
Garnet, 374.
Glockerite, 374.
Gneiss, 84.
Granite, 80, 517, 835.
Granite gneiss, 302.
Granite porphyry, 794.
Granodiorite, 1180.
Granophyre, 517.
Graphite ore, 231.
Greenalite, 1132.
Grünerite-magnetite schist, 1132.
Gypsite, 560.
Gypsum, 164, 250, 437.
Hinsdalite, 665.
Hornblende, 889.
Hornblendite, 546.
Howlite, 357.
Iron ore, 48, 84, 209, 285, 292, 329, 397, 481, 616, 688, 689, 835, 1025, 1132.
Lepidomelane, 374.
Lignite, 47, 865.

CHEMICAL ANALYSES—Continued.

Limestone, 161, 433, 437, 486, 573.
Limonite, 182.
Magnesite, 397.
Marble, 433.
Meteorites, 378.
Microcline, 374.
Mine waters, 157, 373, 616, 1132.
Moldavite, 767.
Molding sand, 309.
Mud, 1144.
Muscovite, 374.
Natramblygonite, 975.
Natrolite, 374.
Natural gas, 679.
Nelsonite, 1095.
Nephelite, 390, 981.
Nephelite basanite, 546.
Obsidianite, 767.
Ocher, 481.
Oligoclase, 374.
Olivine diabase, 517.
Orthoclase, 374, 889.
Pearcite, 1135, 1137.
Pegmatite, 1095.
Peridotite, 206.
Petroleum, 1184, 1243.
Phosphate rock, 407.
Piedmontite, 374.
Pimelite, 374.
Platinum ore, 204.
Plumbojarosite, 179.
Polybasite, 1135.
Prehnite, 374.
Prochlorite, 374.
Pyromorphite, 374.
Pyroxene, 374.
Quartz diabase, 517.
Quartz gabbro, 517.
Quartz monzonite, 302.
Quartzite, 1132.
Rhyolite, 461, 1114.
Rock salt, 122.
Salt brines, 274.
Sand, 250.
Serpentine, 285, 374, 481, 1114.
Scheelite, 374.
Shale, 437, 573, 781, 941, 1036.
Siderite, 48.
Slate, 348, 1132.
Sodalite, 8.
Stibiotantalite, 392.
Stilbite, 374.
Strüverite, 492.
Syenite, 794.
Taconite, 1132.
Talc, 374.
Tektites, 767.
Tetrahedrite, 550.
Thaumasite, 177.
Thomsonite, 208.
Tourmaline, 374.
Tuff, 337, 1024.
Turgite, 374.
Turquoise, 979.
Uralose, 949.
Valencianite, 1232.
Variscite, 985.
Vermiculite, 374.
Water, 236, 382, 462, 463, 568, 759, 760, 840, 844, 886, 1051, 1256.
Wernerite, 374.
Zeolite, 374.
Zoisite, 374.

MINERALS DESCRIBED.

[The numbers refer to entries in this bibliography.]

Adularia, 927.
Agalmatolite, 927.
Analcite, 331.
Anglesite, 92.
Anhydrite, 559, 924.
Anorthite, 95.
Antlerite, 936.
Apatite, 298, 627, 936.
Aragonite, 630.
Argentite, 298.
Augite, 627, 936.
Aurichalcite, 927.
Aurobismuthinite, 604.
Axinite, 927.
Azurite, 92, 835.
Baddeleyite, 922.
Barbierite, 936, 943.
Barite, 298, 1171.
Beaverite, 936.
Bindheimite, 92.
Boracite, 85.
Bornite, 1171.
Bowlingite, 1230.
Britholite, 85.
Brochantite, 927.
Cacoxenite, 298.
Calamine, 835.
Calcite, 298, 627.
Californite, 927.
Carnegieite, 95.
Carnotite, 1187.
Carphosiderite, 936.
Cassiterite, 936.
Cerargyrite, 298.
Ceruleite, 197.
Cerusite, 92.
Chalcanthite, 1171.
Chalcocite, 1171.
Chalcopyrite, 298, 1171.
Chiolite, 86.
Chlorite, 1237.
Chrysoberyl, 1199.
Cinnabar, 11, 298.
Collophanite, 925, 936.
Corellite, 1171.
Corkite, 936.

MINERALS DESCRIBED—Continued.

Crocidolite, 927.
Cryolite, 85, 86.
Cryolithionite, 86.
Cuprite, 1171.
Cuprodescloizite, 936.
Cyanite, 1166.
Dahllite, 925, 936.
Datolite, 627.
Deweylite, 927.
Diamond, 556.
Durangite, 197.
Embolite, 298.
Enargite, 1171.
Epidote, 627.
Feldspar, 627.
Ferritungstite, 936, 937.
Fluorite, 87, 92, 627.
Francolite, 936.
Galena, 92, 298.
Garnet, 219.
Gearksutite, 86.
Glauconite, 1230.
Gold, 298.
Gold, native, 1162.
Goslarite, 1171.
Goyazite, 936.
Greenalite, 1230.
Greenockite, 11.
Gypsum, 609, 924, 1134.
Halloysite, 927.
Hamlinite, 936.
Hematite, 1166.
Hinsdalite, 634, 936.
Howlite, 299.
Hübnerite, 298.
Hydrozincite, 927.
Ilmenite, 1156.
Ilmenorutile, 936.
Iodyrite, 298.
Jamesonite, 92.
Jarosite, 298, 927.
Kalinite, 927.
Kämmererite, 927.
Lapis lazuli, 927.
Laumontite, 627.
Lazulite, 927, 1166.
Lead, 927.
Limonite, 92, 1171.
Liskeardite, 197.
Lorandite, 923.
Ludwigite, 927.
Malachite, 92.
Manganite, 298.
Manganocalcite, 298.
Marcasite, 12, 633, 1171.
Massicot, 92.
Metacinnabar, 11.
Metacinnabarite, 927.
Mica, 627.
Microlite, 927.
Mimetesite, 835.
Mimetite, 92, 604.
Molybdenite, 1171.
Mosesite, 936.
Natramblygonite, 936.
Natrojarosite, 604.
Neocolemanite, 299.
Nepheline, 942.
Nephelite, 95, 332.
Olivine, 627.
Opal, 298, 613.
Orthoclase, 929, 956.
Pachnolite, 86, 87.
Palaite, 939.
Parisite, 824.
Perovskite, 35.
Pharmacosiderite, 298.
Piedmontite, 927.
Pitticite, 927.
Plumbojarosite, 936.
Podolite, 925, 936.
Polybasite, 298.
Pryochlore, 927.
Pseudomalachite, 298.
Psilomelane, 298.
Pyrargyrite, 298.
Pyrite, 12, 92, 298, 633, 1171, 1199, 1263.
Pyrolusite, 92, 298.
Pyrophyllite, 927, 1166.
Pyroxene, 1199.
Pyrrhotite, 12, 633.
Quartz, 92, 298, 627, 864.
Quercyite, 936.
Ralstonite, 86.
Rhodochrosite, 298.
Rhodonite, 1171.
Rutile, 1156, 1166.
Rutile minerals, 936.
Sal-ammoniac, 927.
Salmonsite, 939.
Saponite, 1230.
Sapphirine, 1156.
Schernikite, 719.
Schulite, 692.
Scorodite, 927.
Seladonite, 604.
Selenite, 1062.
Sheridanite, 1237.
Sicklerite, 939.
Sillimanite, 1162.
Silver, 298.
Specularite, 92.
Sphalerite, 11, 92, 298, 1171.
Spinel, 92.
Stelznerite, 936.
Stewartite, 939.
Stiblobismuthinite, 604.
Stibnite, 558.
Strilverite, 936.
Synchisite, 824.
Tetrahedrite, 92, 1171.
Thalite, 1230.
Thaumasite, 936.
Thomsenolite, 86, 87.
Topaz, 556.
Tourmaline, 944, 1227.
Tridymite, 927.
Trollite, 12.
Turquoise, 820, 936, 938.
Utahite, 936.

MINERALS DESCRIBED—Continued.

Valencianite, 927.
Valentinite, 927.
Vanadinite, 835.
Variscite, 936, 940, 941.
Vesuvianite, 92.
Viridite, 627.
Voelckerite, 925.
Wavellite, 298.
Winchellite, 719.
Wollastonite, 627.
Wurtzite, 11.
Wolframite, 298.
Wulfenite, 298.
Wurtzite, 936.

[The following list is additional to that given on page 144 of Bulletin 524. The numbers refer to entries in that bulletin.]

Allanite, 374.
Allophane, 374.
Alunogen, 374.
Amphibole, 374.
Apatite, 374.
Apophyllite, 374.
Australite, 767.
Autunite, 374.
Barite, 374.
Beryl, 374.
Bindheimite, 374.
Beaverite, 178, 179.
Beryl, 80, 1232.
Billitonite, 767.
Biotite, 374, 874.
Bismuthinite, 374.
Bismutite, 374.
Bornite, 374, 663.
Bournonite, 374.
Britholite, 114.
Calamine, 374, 874.
Cancrinite, 374.
Carnotite, 374.
Celestite, 374.
Cerusite, 374, 534.
Chabazite, 374.
Chalcanthite, 374.
Chalcocite, 374, 663.
Chondrodite, 374.
Clinochlore, 374.
Colemanite, 357.
Collophanite, 986.
Columbite, 374, 492.
Corkite, 179.
Covellite, 947.
Cuprodescloizite, 975.
Cyanite, 374, 1179.
Dahllite, 986.
Datolite, 1232.
Descloizite, 374.
Deweylite, 374.
Eglestonite, 948.
Emerald, 80.
Enargite, 999.
Epidote, 374.
Epsomite, 374.
Erythrite, 374.
Evansite, 224.
Euxenite, 374.
Famatinite, 999.
Feldspar, 1095.
Ferritungstite, 977.
Fluorite, 374, 770.
Francolite, 986.
Gadolinite, 374.
Galena, 374.
Galenite, 876.
Garnet, 374.
Genthite, 374.
Glockerite, 374.
Gold, 439, 876.
Goldfieldite, 999.
Graphite, 1143.
Gummite, 374.
Herderite, 391.
Heterosite, 982.
Hinsdalite, 665.
Howlite, 357.
Hydromagnesite, 374.
Lanthanite, 374.
Lepidomelane, 374.
Limonite, 374.
Marcasite, 1218.
Mica, 80, 874.
Microcline, 374.
Mismite, 976.
Moldavite, 767.
Molybdenite, 374.
Molybdite, 374.
Monazite, 374.
Muscovite, 80, 374.
Natramblygonite, 975.
Natrolite, 374.
Neocolemanite, 357.
Nephelite, 390, 981.
Obsidianite, 767.
Oligoclase, 374.
Orthoclase, 374, 950.
Pearceite, 1135, 1137.
Pectolite, 374.
Petzite, 329.
Phlogopite, 874.
Piedmontite, 374.
Pimelite, 374.
Plumbojarosite, 179
Polybasite, 1135.
Prehnite, 374.
Prochlorite, 374.
Psilomelane, 374.
Purpurite, 982.
Pyrite, 876, 1218.
Pyromorphite, 123, 374.
Pyroxene, 374.
Pyrrhotite, 374, 1034.
Quartz, 80, 770.
Raspite, 1233.

MINERALS DESCRIBED—Continued.

Rhodonite, 393.
Rhyolite, 374.
Rutile, 874, 1179.
Sahlite, 374.
Scheelite, 374.
Serpentine, 374.
Siderite, 374.
Smithsonite, 374.
Sphalerite, 374.
Spodumene, 492.
Stibiotantalite, 392.
Stilbite, 374.
Stilpnomelane, 374.
Strüverite, 492.
Talc, 374.
Tetrahedrite, 374.
Thaumasite, 177.
Thomsonite, 208.
Topaz, 80, 374.
Torbernite, 374.
Tourmaline, 80, 374.
Turgite, 374.
Turquoise, 979.
Uraninite, 374.
Uranophane, 374.
Valencianite, 950, 1232.
Variscite, 985.
Wavellite, 374.
Wernerite, 374.
Wurtzite, 179.
Xenotime, 374.
Zaratite, 374.
Zeolite, 374.
Zincite, 863.
Zircon, 374.
Zoisite, 374.

ROCKS DESCRIBED.

[The numbers refer to entries in this bibliography.]

Adamellite, 127.
Alaskite, 680, 1037, 1171.
Alaskite porphyry, 1037.
Albite diorite, 594.
Amphibolite, 817.
Amphibolite schist, 817.
Andesite, 51, 92, 450, 832, 1037, 1171, 1261.
Andesite porphyry, 1168.
Andesite tuff, 92.
Aplite, 127, 1171, 1261.
Auganite, 1224.
Augite diorite, 594.
Augite lamprophyre, 123.
Augite porphyrite, 655.
Augite trachyte, 655.
Basalt, 39, 1261.
Biotite granite, 1037.
Diabase, 51, 127, 627.
Diorite, 92, 127, 817, 1261.
Diorite porphyry, 92, 594.
Dolomite, 680.
Epidote gneiss, 680.
Fanglomerate, 639.
Feldspar porphyry, 123.
Feldsparphyre, 627.
Felsite, 627, 817.
Gabbro, 680, 765, 817.
Gabbro aplite, 627.
Gneiss, 680, 839, 1143, 1166.
Granite, 51, 617, 765, 817, 1171.
Granite gneiss, 680.
Granodiorite, 1168.
Granophyre, 627.
Greenstone, 1230.
Hornblende schist, 680.
Hornblendite, 123.
Kallerudose, 51.
Keratophyre, 627.
Kersantite, 127.
Kinzigite, 680.
Lassenose, 51.
Lava, 51.
Limestone, 839.
Liparose, 51.
Melaphyre, 627.
Mica schist, 817.
Micropegmatite, 627.
Minette, 617.
Monzonite, 1171.
Nephelite, 94.
Norite, 127.
Noyangose, 51.
Obsidian, 627.
Olivine diabase, 1168.
Ophite, 627.
Pegmatite, 617.
Pelites, 617.
Peridotite, 92.
Porphyrite, 127, 627.
Porphyry, 627, 1166.
Psammites, 617.
Psephites, 617.
Pulaskite porphyry, 655.
Quartz, 1171.
Quartz-biotite schist, 680.
Quartz diorite, 92.
Quartz diorite porphyry, 92.
Quartz porphyry, 1037.
Quartzite, 680.
Quartzophyre, 627.
Rhyolite, 450, 627, 1171.
Rhyolite dacite, 1171.
Rhyolite porphyry, 1171.
Schist, 817, 1166.
Serpentine, 123, 1230.
Syenite, 127.
Toscanose, 51.
Trachyte, 627.
Tuff, 627.
Urbainite, 1156.
Wielandite, 778.

ROCKS DESCRIBED—Continued.

[The following list is additional to that given on page 145 of Bulletin 524. The numbers refer to entries in that bulletin.]

Actinolite, 374.
Albitite, 804.
Almandite, 374.
Andesite, 497, 1119.
Andradite, 374.
Asbestos, 374.
Asbolite, 374.
Augite, 374.
Basalt, 485, 497.
Bastite rock, 429.
Bowenite, 374.
Byssolite, 374.
Chrysotile, 374.
Corundum syenite, 949.
Cyanite schist, 1179.
Damourite, 374.
Diabase, 473, 804, 1114, 1220.
Diopside, 374.
Diorite, 1260.
Diorite porphyry, 836.
Eastonite, 374.
Ferrodolomite, 518.
Gabbro, 473, 804, 871, 1119, 1220.
Gneiss, 94, 374, 429, 794.
Granite, 80, 94, 302, 400, 473, 663, 871, 1260.
Granite gneiss, 302, 429.
Granite porphyry, 794.
Granodiorite, 94, 473, 497, 836, 1260.
Greenalite, 1132.
Greenstone, 799.
Grossularite, 374.
Hornblende gneiss, 429.
Jade, 374.
Jaspilite, 1132.
Kaersutite, 485.
Lennilite, 374.
Limestone, 94.
Marmolite, 374.
Nephrite, 374.
Pegmatite, 80, 84, 94, 302, 374.
Peridotite, 206, 485.
Picrite, 485.
Porcellophite, 374.
Porphyry, 302.
Pyrallolite, 374.
Quartz diorite porphyry, 799.
Quartz-sericite schist, 1179.
Quartzite, 429, 794.
Rhyolite, 497, 1114.
Schist, 94, 374, 794.
Serpentine, 1114.
Shenite, 374.
Syenite, 374, 794.
Taconite, 1132.
Thermophyllite, 374.
Thulite, 374.
Tremolite, 374.
Uralose, 949.
Vermiculite, 374.
Williamsite, 374.

GEOLOGIC FORMATIONS DESCRIBED.

Abitibi group (Keewatin?), pré-Cambrian, Quebec: Wilson, 1221.
Abrams mica schist, Oregon and California: Hershey, 452.
Acadian group, Cambrian, New York: Hartnagel, 432.
Adams Lake greenstone, pre-Cambrian, British Columbia: Daly, 254.
Adams Lake volcanic series, pre-Cambrian, British Columbia: Daly, 255.
Aftonian interglacial deposits, Quaternary, South Dakota: Shimek, 976.
Afton terrane, Quaternary, Iowa: Keyes, 577.
Aguacate series, Costa Rica: Romanes, 931.
Alazan shales, Eocene, Mexico: Dumble, 294.
Albert Canyon division, pre-Cambrian, British Columbia: Daly, 254.
Albert series, Carboniferous, New Brunswick: Young, 1259.
Allegheny formation, Pennsylvanian, Pennsylvania: Munn, 782.
Allegheny formation, Pennsylvanian, West Virginia, Kentucky: Phalen, 850.
Allensville bed, Mississippian, Ohio: Hyde, 528.
Allentown limestone, Cambrian, Pennsylvania: Miller, 757; Peck, 839.
Allison Creek sandstone, Cretaceous, Alberta: Leach, 643.
Altamont limestone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Ames limestones, Carboniferous, West Virginia: Hennen, 447.
Ames(?) limestone member, Pennsylvanian, Ohio, West Virginia, Kentucky: Phalen, 850.
Amnicon formation, pre-Cambrian?, Wisconsin: Thwaites, 1085.
Amsterdam limestone, Ordovician, New York: Hartnagel, 432.
Anamosa terrane, Silurian, Iowa: Keyes, 577.
Anderdon limestone beds, Devonian, Ontario and Michigan: Nattress, 793.
Angola shale, Devonian, New York: Hartnagel, 432.
Animas formation, Tertiary, Colorado: Lee, 648.
Animas interglacial interval, Quaternary, Colorado: Atwood and Mather, 32.
Ankareh shale, Triassic, Idaho and Utah: Richards and Mansfield, 903.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Ankareh shale, Triassic, Utah: Boutwell, 92.
Anvil-rock sandstone, Carboniferous, Kentucky: Glenn, 371.
Apishapa shale, Upper Cretaceous, Colorado: Stose, 1056.
Apison shale, Cambrian, Georgia: Maynard, 738.
Appanoose terrane, Carboniferous, Iowa: Keyes, 577.
Aquashicola formation, Silurian, Pennsylvania: Miller, 757.
Aquia formation, Eocene, Maryland: Miller, 758.
Aquia formation, Eocene, Virginia: Clark and Miller, 192.
Arapahoe formation, Tertiary, Colorado: Richardson, 909.
Arcturus formation, Carboniferous, Nevada: Hershey, 452.
Ardness formation, Mississippian, Nova Scotia: Williams, 1211.
Arikaree formation, Oligocene and Miocene, Nebraska: Osborn, 815.
Arisaig series, Silurian, Nova Scotia: Williams, 1211.
Armuchee chert, Devonian, Georgia: Maynard, 738.
Arnheim formation, Ordovician, Ohio and Kentucky: Foerste, 328.
Arnoldsburg sandstone, Carboniferous, West Virginia: Hennen, 447.
Arundel formation, Cretaceous, Maryland: Berry, 67.
Ashbed group, Cambrian, Michigan: Lane, 627.
Atchison terrane, Cretaceous, Iowa: Keyes, 577.
Atkinson terrane, Ordovician, Iowa: Keyes, 577.
Attwood series, Carboniferous, British Columbia: LeRoy, 655.
Aurora sandstone, Mississippian, Ohio: Prosser, 872.
Aylmer formation, Ordovician, Ontario: Raymond, 888.
Bailey formation, Silurian, Missouri: Crane, 233.
Bald Mountain limestone, Ordovician, New York: Clarke, 198.
Bandera shale, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Bangor formation, Mississippian, Georgia: Maynard, 738.
Barnegat limestone, Cambrian, New York: Hartnagel, 432.
Bathurst formation, Carboniferous, New Brunswick: Young, 1258.
Baxters Brook formation, Upper Cambrian, Nova Scotia: Williams, 1211.
Bayfield group, pre-Cambrian?, Wisconsin: Thwaites, 1085.
Bayne series, Eocene, Washington: Evans, 313.
Bays sandstone, Ordovician, Tennessee: Gordon and Jarvis, 383.
Beacon Hill formation, Quaternary, New York: Hartnagel, 432.
Beale diorite, Jurassic and Cretaceous?, British Columbia: Clapp and Allan, 185.
Bearpaw shale, Cretaceous, Montana: Pepperberg, 842.
Bear River formation, British Columbia: McConnell, 695, 696.
Beauharnois formation, Ordovician, Ontario: Raymond, 888.
Beaver limestone, Cambrian, Georgia: Maynard, 738.
Beaverburk limestone, Texas: Udden and Phillips, 1121.
Beckwith formation, Cretaceous and Jurassic, Idaho and Utah: Richards and Mansfield, 903.
Becraft limestone, Devonian, New York: Hartnagel, 432; Kindle, 581.
Bedford formation, Carboniferous, Ohio: Prosser, 871.
Bedford formation, Mississippian, Ohio: Hyde, 528.
Bedford shale, Carboniferous, Ohio: Prosser, 871.
Bedford shale, Devonian, Ohio: Girty, 370; Prosser, 872.
Bedford shale, Mississippian, Ohio: Stauffer, 1025.
Bedford shale, Waverlyan, Ohio: Ulrich, 1122.
Beechhill Cove formation, Silurian, Nova Scotia: Williams, 1211.
Beekmantown, Ordovician, Pennsylvania: Ziegler, 1262.
Beekmantown, Ordovician, Vermont: Perkins, 845.
Beekmantown formation, Ordovician, Ontario: Raymond, 888.
Beekmantown limestone, Ordovician, New York: Hartnagel, 432.
Beekmantown limestone, Ordovician, West Virginia: Stose and Swartz, 1058.
Belledune group, Silurian, New Brunswick: Young, 1258.
Bellvale flags, Devonian, New York: Hartnagel, 432.
Belly River formation, Cretaceous, Alberta: Ries and Keele, 916.
Belt series, pre-Cambrian, Idaho and Nevada: Hershey, 452.
Bend formation, Texas: Udden and Phillips, 1121.
Benson formation, Cretaceous, British Columbia: Clapp, 183.
Benton formation, Cretaceous, Alberta: Leach, 643.
Benton formation, Cretaceous, Manitoba: Ries and Keele, 916.
Benton formation, Cretaceous, Wyoming: Jamison, 540.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Benton group, Cretaceous, Kansas: Parker, 826.
Benton shale, Cretaceous, Wyoming: Wegemann, 1178.
Benwood limestone, Carboniferous, West Virginia: Hennen, 447.
Benwood limestone member, Pennsylvanian, Pennsylvania: Munn, 782.
Berea grit, Carboniferous, Ohio: Prosser, 871.
Berea grit, Mississippian, Ohio: Hyde, 528; Stauffer, 1025.
Berea grit, Waverlyan, Ohio: Ulrich, 1122.
Berea sandstone, Carboniferous, Ohio: Prosser, 871.
Berea sandstone, Mississippian, Ohio: Prosser, 872.
Berners formation, upper Jurassic or lower Cretaceous, Alaska: Knopf, 594.
Bertie water lime, Silurian, New York: Hartnagel, 432.
Bertram terrane, Silurian, Iowa: Keyes, 577.
Bethany terrane, Cretaceous, Iowa: Keyes, 577.
Big Horn epoch, Quaternary, Colorado: Atwood and Mather, 32.
Big Horn glacial epoch, Quaternary, Colorado: Atwood and Mather, 32.
Binnewater sandstone, Silurian, New York: Hartnagel, 432.
Birch Creek schist, pre-Ordovician?, Alaska: Capps, 170; Moffit, 769.
Birdseye limestone, Ordovician, Ohio: Fuller and Clapp, 346.
Birdsville formation, Carboniferous, Illinois: Shaw, 970.
Birdsville formation, Mississippian, Illinois: Lines, 670; Shaw and Savage, 972.
Birdsville formation, Mississippian, Missouri: Crane, 233.
Birmingham shale, Carboniferous, West Virginia: Hennen, 447.
Bishop conglomerate, Tertiary, Utah: Lupton, 689, 690.
Bitter Creek formation, British Columbia: McConnell, 696.
Biwabik formation, pre-Cambrian, Minnesota: Van Barneveld, 1133.
Black Creek formation, Cretaceous, North Carolina: Clark *et al.*, 193.
Black Hand formation, Mississippian, Ohio: Stauffer, 1025.
Black River, Ordovician, Vermont: Perkins, 845.
Black River beds, Ordovician, New York: Hartnagel, 432.
Black River formation, Ordovician, Ontario: Raymond, 888.
Black River group, Ordovician, Ontario: Johnston, 557.
Black River limestones, Ordovician, Pennsylvania: Ziegler, 1262.
Blacksmith limestone, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
Blakely formation, Miocene, Washington: Weaver, 1169.
Blanchester division, Ordovician, Ohio and Kentucky: Foerste, 327.
Bloomington formation, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
Bloomsburg red sandstone member, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Bloomsbury formation, Devonian, New Brunswick: Ells, 307.
Bluefield formation, Mississippian, Virginia: Branson, 103.
Bluff bone bed, Texas: Udden and Phillips, 1121.
Bohemian Range group, Cambrian, Michigan: Lane, 627.
Bonaventure formation, Devonian, New Brunswick: Young, 1258.
Bonneterre formation, Cambrian, Missouri: Crane, 233.
Boone chert, Mississippian, Oklahoma: Snider, 1005.
Bossardville limestone, Silurian, New York: Hartnagel, 432.
Boston Bar series, Carboniferous, British Columbia: Camsell, 162.
Boston Neck granite, post-Carboniferous, Rhode Island: Lahee, 617.
Bosworth formation, Cambrian, British Columbia: Allan, 9.
Bowie shale member, Cretaceous, Colorado: Lee, 647.
Bradford division, Mississippian, New York: Hartnagel, 432.
Brainard terrane, Ordovician, Iowa: Keyes, 577.
Brayman shale, Ordovician or Silurian, New York: Hartnagel, 432.
Breathitt formation, Carboniferous, Kentucky: Miller, 756.
Brecksville shale, Mississippian, Ohio: Prosser, 872.
Bridger formation, Eocene, Wyoming: Osborn, 815.
Bridger formation, Tertiary, Utah: Lupton, 690.
Bridgeton formation, Quaternary, New York: Hartnagel, 432.
Brierfield dolomite, Alabama: Butts, 148.
Brigham quartzite, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
Bristol limestone, Carboniferous, West Virginia: Hennen, 447.
Brock shales, Triassic, California: Smith, 995.
Brooklyn formation, Carboniferous, British Columbia: LeRoy, 655.
Brown's Mountain group, Nova Scotia: Williams, 1211.
Browntown sandstone member, Pennsylvanian, Pennsylvania: Munn, 782.
Brule formation, Tertiary, South Dakota: Perisho and Visher, 843.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Brunswick beds, Jura-Trias, New York: Hartnagel, 432.
Brunswick formation, Triassic, Pennsylvania, New Jersey: Wherry, 1101.
Buena Vista member, Devonian, Ohio: Prosser, 872.
Buffalo sandstone, Carboniferous, West Virginia: Hennen, 447.
Buffalo sandstone member, Pennsylvanian, Ohio, West Virginia, Kentucky: Phalen, 850.
Bulkley eruptives, Tertiary?, British Columbia: Malloch, 715.
Burden conglomerate, Ordovician, New York: Hartnagel, 432.
Burgen sandstone, Ordovician, Oklahoma: Snider, 1005.
Burgess shale, Cambrian, British Columbia: Walcott, 1152.
Burgoon sandstone member, Mississippian, Pennsylvania: Munn, 782.
Burke formation, pre-Cambrian, Idaho: Hershey, 452.
Burlington formation, Mississippian, Missouri: Crane, 233.
Burlington limestone, Mississippian, Illinois: Lines, 670; Udden, 1117.
Burlington terrane, Carboniferous, Iowa: Keyes, 577.
Burton sandstone, Carboniferous, West Virginia: Hennen, 447.
Bushberg sandstone, Devonian, Missouri: Crane, 233.
Buxton formation, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Byer sandstone, Mississippian, Ohio: Hyde, 528.
Cache Creek formation, Carboniferous, British Columbia: Camsell, 162.
Calciferous formation, Ordovician, Quebec: Valiquette, 1132.
Caledonia group, pre-Carboniferous, New Brunswick: Young, 1259.
Calvert formation, Miocene, Maryland: Miller, 758.
Calvert formation, Miocene, Virginia: Clark and Miller, 192.
Cambric or **Taconic** system: Hartnagel, 432.
Cambridge (lower) limestone, Pennsylvanian, Ohio, West Virginia, Kentucky: Phalen, 850.
Camillus shale, Silurian, New York: Hartnagel, 432.
Canadian group, Ordovician: Hartnagel, 432.
Canajoharie shale, Ordovician, New York: Hartnagel, 432.
Cap Mountain formation, Cambrian, Texas: Paige, 817.
Capote quartzite, Cambrian, Mexico: Lee, 645.
Carbondale formation, Carbondale, Illinois: Shaw, 970.
Carbondale formation, Pennsylvanian, Illinois: Lines, 670; Shaw and Savage, 972.
Carbonic system: Hartnagel, 432.
Cardiff shale, Devonian, New York: Hartnagel, 432.
Carlile shale, Upper Cretaceous, Colorado: Stose, 1056.
Carlinville limestone, Pennsylvanian, Illinois: Lines, 670.
Carmack basalts, Tertiary or Pleistocene, Yukon: Cairnes, 149.
Carmanah formation, Oligocene-Miocene, British Columbia: Clapp and Allan, 185.
Carmanah formation, Tertiary, British Columbia (Vancouver Island): Clapp, 182.
Carmichaels formation, Quaternary, Pennsylvania: Munn, 782.
Caseyville formation, Pennsylvanian, Kentucky: Glenn, 373.
Cashaqua shale, Devonian, New York: Hartnagel, 432.
Cassin formation, Ordovician, New York: Hartnagel, 432.
Cassville plant shale, Carboniferous, West Virginia: Hennen, 447.
Cassville shale member, Permian, Pennsylvania: Munn, 782.
Castle Hayne limestone, Eocene, North Carolina: Clark *et al.*, 193.
Castle Rock conglomerate, Oligocene, Colorado: Richardson, 908.
Cataldo formation, pre-Cambrian, Idaho: Hershey, 452.
Cataldo formation, pre-Cambrian, Idaho: Huston, 527.
Cathedral formation, Cambrian, British Columbia: Allan, 9.
Cat Hill granite, pre-Cambrian, New York: Hartnagel, 432.
Catskill beds, Devonian, New York: Hartnagel, 432.
Catskill formation, Devonian, New York and Pennsylvania: Barrell, 48.
Catskill (?) formation, Devonian, Pennsylvania: Munn, 782.
Catskill formation, Devonian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Cattaraugus beds, Mississippian, New York: Hartnagel, 432.
Cayuga group, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Cayugan group, Silurian, New York: Hartnagel, 432.
Cayuta shale, Devonian, New York: Hartnagel, 432.
Cedar district formation, Cretaceous, British Columbia: Clapp, 183.
Cedar Valley limestone, Devonian, Iowa: Norton *et al.*, 800.
Cenozoic series: Hartnagel, 432.
Centerville limestone, Devonian, New York: Hartnagel, 432.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Central (Mine) group, Cambrian, Michigan: Lane, 627.
Chadron beds, Tertiary, South Dakota: Perisho and Visher, 843.
Chagrin formation, Devonian, Ohio: Prosser, 872; Ulrich, 1122.
Chagrin shale, Ohio: Cushing, 246.
Chagrin shale, Devonian, Ohio: Kindle, 581.
Champlainic or Ordovicic system: Hartnagel, 432.
Chancellor formation, Cambrian, British Columbia: Allan, 9; Walcott, 1146.
Channahon limestone, Silurian, Illinois: Savage, 985.
Chardon sandstone, Mississippian, Ohio: Prosser, 872.
Chattanooga black shale, Devonian, Georgia: Maynard, 738.
Chattanooga shale, Devonian, Kentucky: Kindle, 582.
Chattanooga shale, Devonian, Oklahoma: Snider, 1005.
Chattanoogan series: Ulrich, 1122.
Chautauquan group, Devonian, New York: Hartnagel, 432.
Chazy, Ordovician, Vermont: Perkins, 845.
Chazy beds, Ordovician, New York: Hartnagel, 432.
Chazy formation, Ordovician, Ontario: Raymond, 888.
Chazy limestone, Ordovician, Quebec: Valiquette, 1132.
Chazyan, Ordovician, Pennsylvania: Ziegler, 1262.
Chehalis formation, Miocene, Washington: Weaver, 1169.
Chemung beds, Devonian, New York: Hartnagel, 432.
Chemung formation, Devonian, New York and Pennsylvania: Barrell, 48.
Chemung (?) formation, Devonian, Pennsylvania: Munn, 782.
Chemung group, Mississippian, Missouri: Crane, 233.
Chequamegon sandstone, pre-Cambrian, Wisconsin: Thwaites, 1085.
Cherokee formation, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Cherokee formation, Pennsylvanian, Missouri: Crane, 233.
Cherokee shale, Pennsylvanian, Missouri: Hinds, 470.
Cherokee terrane, Carboniferous, Iowa: Keyes, 577.
Cherry Valley limestone, Devonian, New York: Hartnagel, 432.
Chesapeake group, Miocene, Maryland: Miller, 758.
Chesapeake group, Miocene, Virginia: Clark and Miller, 192.
Chester (Huron) formation, Mississippian, Indiana: Cumings, 244.
Chester group, Mississippian, Missouri: Crane, 233.
Chickaloon formation, Tertiary, Alaska: Martin and Katz, 722.
Chickamauga, Ordovician, Tennessee: Gordon and Jarvis, 383.
Chickamauga formation, Ordovician, Georgia: Maynard, 738.
Chico formation, Cretaceous, California: Dumble, 293.
Chieftain Hill volcanics, Cretaceous, Yukon: Cairnes, 149.
Chinech formation, California: Hershey, 452.
Chinitna shale, Jurassic, Alaska: Martin and Katz, 721.
Chisik conglomerate, Jurassic, Alaska: Martin and Katz, 721.
Choptank formation, Miocene, Maryland: Clark and Miller, 192; Miller, 758.
Chouteau limestone, Carboniferous, Iowa, Missouri: Keyes, 578.
Chouteau limestone, Mississippian, Missouri: Crane, 233.
Chouteau terrane, Carboniferous, Iowa: Keyes, 577.
Chowan formation, Pleistocene, North Carolina: Clark *et al.*, 193.
Chugwater formation, Triassic, Wyoming: Jamison, 539.
Cincinnati shale, Ordovician, Illinois: Udden, 1117.
Cincinnatian group, Ordovician: Hartnagel, 432.
Cincinnatus flags, Devonian, New York: Hartnagel, 432.
Cinnemousun limestone, pre-Cambrian, British Columbia: Daly, 254.
Cisco formation, Texas: Udden and Phillips, 1121.
Claggan terrane, Devonian, Iowa: Keyes, 577.
Claggett formation, Cretaceous, Montana: Pepperberg, 842.
Clarksburg fire-clay shale, Carboniferous, West Virginia: Hennen, 447.
Clarksburg limestone, Carboniferous, West Virginia: Hennen, 447.
Clarksburg red shale, Carboniferous, West Virginia: Hennen, 447.
Clarksville division, Ordovician, Ohio and Kentucky: Foerste, 327.
Claysville limestone member, Permian, Pennsylvania: Munn, 782.
Clear Creek chert, Devonian, Illinois: Lines, 670.
Clear Creek (Oriskany) formation, Devonian, Missouri: Crane, 233.
Clermont terrane, Ordovician, Iowa: Keyes, 577.
Cleveland shale, Ohio: Cushing, 246.
Cleveland shale, Devonian, Ohio: Kindle, 581; Prosser, 872.
Cleveland shale, Waverlyan, Ohio: Ulrich, 1122.
Clinch formation, Silurian, Tennessee: Gordon and Jarvis, 383.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Clinton beds, Silurian, New York: Hartnagel, 432.
Clinton limestone, Silurian, Illinois: Lines, 670.
Clinton limestone, Silurian, Ohio: Fuller and Clapp, 346.
Clinton shale, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Cloche Island beds, Ordovician, Ontario: Foerste, 329.
Coast Range intrusives, Jurassic, Yukon: Cairnes, 149.
Cobalt series, pre-Cambrian, Ontario: Burrows, 137.
Cobalt series, pre-Cambrian, Quebec: Wilson, 1221.
Cobalt series, upper Huronian, Ontario: McMillan, 709.
Cobleskill limestone, Silurian, New York: Hartnagel, 432.
Coboconk limestone, Ordovician, Ontario: Johnston, 557.
Coeymans limestone, Devonian, New York: Hartnagel, 432; Kindle, 581.
Coffeyville formation, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Cohansey formation, Quaternary, New York: Hartnagel, 432.
Coharie formation, Pleistocene, North Carolina: Clark *et al.*, 193.
Colesburg terrane, Silurian, Iowa: Keyes, 577.
Colgate sandstone member, Cretaceous or Tertiary, Montana: Beekly, 63.
Colgate sandstone member, Tertiary, Montana: Calvert, 157.
Collingwood formation, Ordovician, Ontario: Foerste, 329; Raymond, 888.
Colorado shale, Cretaceous, Montana: Calvert, 158, 159; Pepperberg, 842.
Columbia group, Pleistocene, North Carolina: Clark *et al.*, 193.
Columbia group, Pleistocene, Virginia: Clark and Miller, 192.
Columbus limestone, Devonian, Ohio: Stauffer, 1025.
Comanche series, Cretaceous, Texas: Paige, 817.
Comanche Peak limestone, Cretaceous, Texas: Paige, 817.
Comox formation, British Columbia: Clapp, 184.
Conasauga, Cambrian, Tennessee: Gordon and Jarvis, 383. *See also* Connasauga.
Conemaugh formation, Pennsylvanian, Ohio, West Virginia, Kentucky: Phalen, 850.
Conemaugh formation, Pennsylvanian, Pennsylvania: Munn, 782.
Conemaugh series, Carboniferous, West Virginia: Hennen, 447.
Connasauga shales and limestones, Cambrian, Georgia: Maynard, 738.
Connellsville sandstone, Carboniferous, West Virginia: Hennen, 447.
Connelly conglomerate, Devonian, New York: Hartnagel, 432.
Conococheague limestone, Cambrian, West Virginia: Stose and Swartz, 1058.
Conway mica schist, Vermont: Hitchcock, 473.
Coplay limestone, Ordovician, Pennsylvania: Miller, 757; Peck, 839.
Coralville terrane, Devonian, Iowa: Keyes, 577.
Corbin conglomerate, Carboniferous, Kentucky: Miller, 756.
Cornishville member, Ordovician, Kentucky: Foerste, 327.
Cornwall shale, Devonian, New York: Hartnagel, 432.
Corry standstone, Mississippian, Ohio: Prosser, 872.
Cortlandt series, pre-Cambrian, New York: Hartnagel, 432.
Coutchiching series, pre-Cambrian, Ontario: Lawson, 636, 637.
Cowichan group, Cretaceous, British Columbia (Vancouver Island): Clapp, 182.
Cowichan group, Upper Cretaceous(?), British Columbia: Clapp and Allan, 185.
Cowlitz formation, Eocene, Washington: Weaver, 1169.
Cranberry formation, Cretaceous, British Columbia: Clapp, 183.
Creston formation, Cambrian, British Columbia: Clapp, 183.
Creston formation, Cambrian, British Columbia: Schofield, 953.
Creston red shale, Carboniferous, West Virginia: Hennen, 447.
Cretacic group: Hartnagel, 432.
Crill terrane, Cretaceous, Iowa: Keyes, 577.
Crown Point limestone, Ordovician, New York: Hartnagel, 432.
Crowsnest volcanics, Cretaceous, Alberta: Leach, 643.
Cuba sandstone, Devonian, New York: Hartnagel, 432.
Cumberland Head shale, Ordovician, New York: Hartnagel, 432.
Curlew limestone, Carboniferous, Kentucky: Glenn, 371.
Curlew sandstone, Carboniferous, Kentucky: Glenn, 371.
Cussewago shales and sandstone, Mississippian, Ohio: Prosser, 872.
Cuyahoga formation, Carboniferous, Ohio: Prosser, 871.
Cuyahoga formation, Mississippian, Ohio: Hyde, 528; Stauffer, 1025.
Cuyahoga shale, Mississippian, Ohio: Prosser, 872.
Cypress formation, Mississippian, Missouri: Crane, 233.
Cypress sandstone, Carboniferous, Illinois: Shaw, 970.
Cypress sandstone, Mississippian, Illinois: Lines, 670.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Dakota(?), Cretaceous, Alberta: Leach, 643.
Dakota formation, Cretaceous, Manitoba: Ries and Keele, 916.
Dakota sandstone, Cretaceous, Colorado: Lee, 647, 648.
Dakota sandstone, Cretaceous, Kansas: Parker, 826.
Dakota (?) sandstone, Cretaceous, Utah: Lupton, 689.
Dakota sandstone, Cretaceous, Wyoming: Jamison, 539.
Dakota sandstone, Cretaceous, Wyoming-South Dakota: Stone, 1045.
Dakota (?) sandstone, Cretaceous, Wyoming: Wegemann, 1178.
Dakota sandstone, Upper Cretaceous, Colorado: Stone, 1056.
Davis formation, Cambrian, Missouri: Crane, 233.
Dawson arkose, Eocene, Colorado: Richardson, 908.
Day Point limestone, Ordovician, New York: Hartnagel, 432.
Deadwood formation, Cambrian, Wyoming: Jamison, 539.
Decewsville formation, Ontario: Stauffer, 1024.
Decker Ferry limestone, Silurian, New York: Hartnagel, 432.
Decorah shale, Ordovician, Iowa: Norton *et al.*, 800.
Decorah terrane, Ordovician, Iowa: Keyes, 577.
DeCourcy formation, Cretaceous, British Columbia: Clapp, 183.
Deepkill shale, Ordovician, New York: Hartnagel, 432.
DeKoven formation, Pennsylvanian, Kentucky: Glenn, 373.
Delaware limestone, Devonian, Ohio: Stauffer, 1025.
Derby formation, Cambrian, Missouri: Crane, 233.
Des Moines group, Pennsylvanian, Iowa: Norton *et al.*, 800.
Des Moines group, Pennsylvanian, Missouri: Crane, 233; Hinds, 470.
Devils Island sandstone, pre-Cambrian, Wisconsin: Thwaites, 1085.
Devonic system: Hartnagel, 432.
Dewey limestone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Diamond Peak formation, Nevada: Hershey, 452.
Dixon formation, Pennsylvanian, Kentucky: Glenn, 373.
Dixon sandstone, Carboniferous, Kentucky: Glenn, 371.
Dodge terrane, Cretaceous, Iowa: Keyes, 577.
Doe Run formation, Cambrian, Missouri: Crane, 233.
Dolgeville shale, Ordovician, New York: Hartnagel, 432.
Dolores shale, Triassic, Utah: Woodruff, 1243.
Donley limestone member, Permian, Pennsylvania: Munn, 782.
Douglas shale, Pennsylvanian, Missouri: Hinds, 470.
Doyle shale, Permian, Oklahoma: Ohern and Garrett, 803.
Dresbach sandstone, Cambrian, Iowa: Norton *et al.*, 800.
Dresbach terrane, Cambrian, Iowa: Keyes, 577.
Dunkard series, Carboniferous, West Virginia: Hennen, 447.
Dunkirk shale, Devonian, New York: Hartnagel, 432.
Duplin formation, Miocene, North Carolina: Clark *et al.*, 193.
Eagle sandstone, Cretaceous, Montana: Pepperberg, 842.
Eagle River group, Cambrian, Michigan: Lane, 627.
East Wellington formation, Cretaceous, British Columbia: Clapp, 183.
Eden shale, Ordovician, Ohio: Fuller and Clapp, 346.
Edgewood formation, Silurian, Illinois: Lines, 670.
Edmonton formation, Cretaceous, Alberta: Ries and Keele, 916.
Edwards limestone, Cretaceous, Texas: Paige, 817.
Eileen sandstone, pre-Cambrian, Wisconsin: Thwaites, 1085.
Eldon formation, Cambrian, British Columbia: Allan, 9: Walcott, 1152.
Elgin sandstone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Elgin terrane, Ordovician, Iowa: Keyes, 577.
Elisa quartz monzonite porphyry, Tertiary, Mexico: Lee, 650.
Elk Lick limestone, Carboniferous, West Virginia: Hennen, 447.
Ellenburger limestone, Cambrian and Ordovician, Texas: Paige, 817.
Ellis formation, Jurassic, Montana: Calvert, 159.
Elm Grove limestone, Carboniferous, West Virginia: Hennen, 447.
Elmtree slates, Silurian, New Brunswick: Young, 1258.
Ely formation, Devonian, Nevada: Hershey, 452.
Embar formation, Carboniferous, Wyoming: Jamison, 539.
Eminence formation, Cambrian, Missouri: Crane, 233.
Enfield shale, Devonian, New York: Hartnagel, 432.
Erian group, Devonian: Hartnagel, 432.
Erie shale, Devonian, Ohio: Prosser, 872.
Eska conglomerate, Tertiary, Alaska: Martin and Katz, 722.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Esopus grit, Devonian, New York: Hartnagel, 432.
Esopus shale, Devonian, New York: Kindle, 581.
Essex limestone, Silurian, Illinois: Savage, 935.
Etchegoin division, Miocene, California: Dumble, 293.
Euclid sandstone lentil, Devonian, Ohio: Prosser, 872.
Eureka formation, Nevada: Hershey, 452.
Ewing limestone, Carboniferous, West Virginia: Hennen, 447.
Extension formation, Cretaceous, British Columbia: Clapp, 183.
Fairhaven member, Miocene, Maryland: Miller, 758.
Farnham series, Ordovician, Quebec: Harvie, 433.
Faulconer division, Ordovician, Kentucky: Foerste, 327.
Fayette terrane, Devonian, Iowa: Keyes, 577.
Fayetteville shale, Mississippian, Oklahoma: Snider, 1005.
Fern Glen formation, Missouri: Crane, 233.
Fernie shale, Jurassic, Alberta: Dowling, 285; Leach, 643.
Finnie sandstone, Carboniferous, Kentucky: Glenn, 371.
Fish Creek sandstone, Carboniferous, West Virginia, Hennen, 447.
Fishkill limestone, Cambrian, New York: Hartnagel, 432.
Fishpot ("Sewickley") limestone member, Pennsylvanian, Pennsylvania: Munn, 782.
Flaming Gorge formation, Cretaceous, Utah: Lupton, 689.
Floyd formation, Mississippian, Georgia: Maynard, 738.
Floyd limestone, Devonian, Iowa: Thomas, 1076.
Forbes terrane, Cretaceous, Iowa: Keyes, 577.
Fordham gneiss, pre-Cambrian, New York: Hartnagel, 432.
Fort Ancient division, Ordovician, Ohio and Kentucky: Foerste, 327.
Fort Benton formation, Cretaceous, Wyoming: Jamison, 539.
Fort Hays limestone, Cretaceous, Kansas: Parker, 826.
Fort Payne chert, Mississippian, Georgia: Maynard, 738.
Fort Riley limestone, Permian, Oklahoma: Ohern and Garrett, 803.
Fort Scott formation, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Fort Union formation, Wyoming: Jamison, 539; Winchester, 1231.
Fort Union formation, Eocene, North Dakota: Leonard, 654.
Fort Union formation, Eocene, Wyoming: Davis, 269.
Fort Union formation, Tertiary, Montana: Beekly, 63; Calvert, 157; Herald, 448; Pepperberg, 842.
Fort Union formation, Tertiary, North Dakota: Pishel, 861.
Fort Union formation, Tertiary, Wyoming: Wegemann, 1179; Woodruff and Winchester, 1246.
Fournier group, Ordovician to Devonian, New Brunswick: Young, 1258.
Fox Hills sandstone, Cretaceous, North Dakota: Leonard, 654.
Fox Hills sandstone, Cretaceous, Wyoming: Jamison, 540; Wegemann, 1178, 1179.
Fox Hills sandstone, Wyoming: Winchester, 1231.
Frankfort shale, Ordovician, New York: Hartnagel, 432.
Franklin group, Paleozoic, British Columbia: Drysdale, 289.
Franklin limestone, Algonkian, Pennsylvania: Miller, 757.
Franklin limestone, pre-Cambrian, New York: Hartnagel, 432.
Franklin series, Eocene, Washington: Evans, 313.
Freda sandstone, pre-Cambrian, Wisconsin: Thwaites, 1085.
Freda sandstones, Cambrian, Michigan: Lane, 627.
Fredericksburg group, Cretaceous, Texas: Paige, 817.
Fulton green shale, Carboniferous, West Virginia: Hennen, 447.
Furnaceville iron ore, Silurian, New York: Hartnagel, 432.
Fuson shale, Cretaceous, Wyoming-South Dakota: Stone, 1045.
Gabriola formation, Cretaceous, British Columbia: Clapp, 183.
Galena dolomite, Ordovician, Iowa: Norton *et al.*, 800.
Galena terrane, Ordovician, Iowa: Keyes, 577.
Galena-Trenton limestone, Ordovician, Illinois: Udden, 1117.
Galisteo sandstone, Tertiary?, New Mexico: Lee, 648.
Gardeau flags and shale, Devonian, New York: Hartnagel, 432.
Gasconade formation, Cambrian, Missouri: Crane, 233.
Genesee beds, Devonian, New York: Hartnagel, 432.
Genesee black shale member, Devonian, West Virginia: Stose and Swartz, 1058.
Genesee shale, Devonian, Ontario: Stauffer, 1023.
Georgia beds, Cambrian, New York: Hartnagel, 432.
Georgian group, Cambrian, New York: Hartnagel, 432.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Genundewa limestone, Devonian, New York: Hartnagel, 432.
Gering, Oligocene, Nebraska: Osborn, 815.
Gilbert division, Ordovician, Kentucky: Foerste, 327.
Gilboy sandstone, Carboniferous, West Virginia: Hennen, 447.
Gilmore limestone, Carboniferous, West Virginia: Hennen, 447.
Gilmore sandstone, Carboniferous, West Virginia: Hennen, 447.
Girardeau formation, Silurian, Missouri: Crane, 233.
Girardeau limestone, Silurian, Illinois: Lines, 670.
Glacier division, Cambrian, British Columbia: Daly, 254.
Glenerie limestone, Devonian, New York: Hartnagel, 432.
Glen Park limestone, Devonian, Missouri: Crane, 233.
Glens Falls limestone, Ordovician, New York: Hartnagel, 432.
Glenwood terrane, Ordovician, Iowa: Keyes, 577.
Gloucester formation, Paleozoic, British Columbia: Drysdale, 289.
Goldenville formation, Cambrian or pre-Cambrian, Nova Scotia: Faribault, 318.
Goodridge formation, Carboniferous, Utah: Woodruff, 1243.
Goodsir formation, Ordovician, British Columbia: Allan, 9; Walcott, 1146.
Goose Bay argillite, British Columbia: McConnell, 694.
Goshen mica schist, Vermont: Hitchcock, 473.
Grafton sandstone, Carboniferous, West Virginia: Hennen, 447.
Grand Falls chert, Mississippian, Oklahoma: Snider, 1005.
Graneros shale, Cretaceous, Wyoming-South Dakota: Stone, 1045.
Graneros shale, Upper Cretaceous, Colorado: Stose, 1056.
Grassy black shales, Carboniferous, Iowa, Missouri: Keyes, 578.
Grassy black shale, Carboniferous, Missouri: Keyes, 578.
Grassy terrane, Carboniferous, Iowa: Keyes, 577.
Graves Creek formation, Pleistocene, Kentucky: Glenn, 373.
Graydon sandstone, Pennsylvanian, Missouri: Crane, 233.
Great Copper Harbor conglomerate, Cambrian, Michigan: Lane, 627.
Great Valley limestone, Cambrian, Pennsylvania: Eaton, 303.
Greenbrier limestone, Mississippian, Virginia: Branson, 103.
Greenbrier limestone member, Mississippian, Pennsylvania: Munn, 782.
Green River formation, Eocene, Colorado: Lee, 647.
Green River formation, Tertiary, Utah: Lupton, 690.
Greene formation, Permian, Pennsylvania: Munn, 782.
Greenhorn limestone, Upper Cretaceous, Colorado: Stose, 1056.
Grenville series, New York: Smyth, 1004.
Grenville series, pre-Cambrian, New York: Hartnagel, 432.
Grenville series, pre-Cambrian, Quebec: Stansfield, 1018.
Grimes sandstone, Devonian, New York: Hartnagel, 432.
Guelph dolomite, Silurian, New York: Hartnagel, 432.
Gunflint iron-bearing formation, pre-Cambrian, Minnesota: Zapffe, 1260.
Gunnison formation, Jurassic?, Colorado: Lee, 647.
Gunn Peak formation, Carboniferous?, Washington: Weaver, 1168.
Gunter sandstone member, Cambrian, Missouri: Crane, 233.
Gwynedd formation, Triassic, Pennsylvania: Wherry, 1191.
Halifax formation, Cambrian or pre-Cambrian, Nova Scotia: Faribault, 318.
Hamilton, Devonian, New York: Kindle, 581.
Hamilton beds, Devonian, New York: Hartnagel, 432.
Hamilton beds, Devonian, Ontario: Stauffer, 1023.
Hamilton formation, Devonian, Missouri: Crane, 233.
Hamilton formation, Devonian, Pennsylvania: Miller, 757.
Hamilton limestone and shale, Devonian, Illinois: Lines, 670.
Hamilton shale member, Devonian, West Virginia: Stose and Swartz, 1058.
Hannibal shales, Carboniferous, Iowa, Missouri: Keyes, 578.
Hannibal shale, Mississippian, Missouri: Crane, 233.
Hannibal terrane, Carboniferous, Iowa: Keyes, 577.
Hanover shales, Devonian, New York: Hartnagel, 432.
Hardyston quartzite, Cambrian, Pennsylvania: Miller, 757; Peck, 839.
Harlan sandstone, Carboniferous, Kentucky: Dilworth, 284.
Harrison, Oligocene and Miocene, Nebraska: Osborn, 815.
Harrison diorite, pre-Cambrian, New York: Hartnagel, 432.
Hartwick terrane, Silurian, Iowa: Keyes, 577.
Haslam formation, Cretaceous, British Columbia: Clapp, 183.
Hatch shale and flags, Devonian, New York: Hartnagel, 432.
Hawarden terrane, Cretaceous, Iowa: Keyes, 577.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Hazelton group, Jurassic, British Columbia: Malloch, 715.
Hedges shale, Carboniferous, West Virginia: Stose and Swartz, 1058.
Helderberg limestone, Devonian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Helderbergian group, Devonian: Hartnagel, 432.
Helderbergian series, Devonian, Pennsylvania: Miller, 757.
Henrietta diorite porphyry, Tertiary, Mexico: Lee, 650.
Henrietta formation, Pennsylvanian, Missouri: Crane, 233; Hinds, 470.
Herington limestone, Permian, Oklahoma: Ohern and Garrett, 803.
Hickory sandstone, Cambrian, Texas: Paige, 817.
High Falls shale, Silurian, New York: Hartnagel, 432.
Highpoint sandstone, Devonian, New York: Hartnagel, 432.
Hinton formation, Mississippian, Virginia: Branson, 103.
Hitz layer, Ordovician, Indiana: Foerste, 327.
Hogshooter limestone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Holston, Ordovician, Tennessee: Gordon and Jarvis, 383.
Homewood sandstone member, Pennsylvanian, Kentucky: Phalen, 850.
Hosselkus limestone, Triassic, California: Smith, 995.
Howard arkose formation, Tertiary, Washington: Weaver, 1168.
Hoyt limestone, Cambrian, New York: Hartnagel, 432.
Hozameen series, Carboniferous, British Columbia: Camsell, 164.
Hudson River formation, Ordovician, Missouri: Crane, 233.
Hudson River formation, Ordovician, Pennsylvania: Eaton, 303.
Hundred sandstone, Carboniferous, West Virginia: Hennen, 447.
Huron shale, Devonian, Ohio: Kindle, 581; Prosser, 872.
Huron shale, Waverlyan, Ohio: Ulrich, 1122.
Huronian?, pre-Cambrian, New York: Bancroft, 43.
Huronian, pre-Cambrian, Ontario: Collins, 218; Moore, 780.
Huronian, pre-Cambrian, Ontario and Quebec: Wilson, 1220.
Huronian rocks, pre-Cambrian, Michigan: Lane, 627.
Ice River formation, British Columbia: Burling, 135.
Igaliko sandstone, Devonian?, Greenland: Ussing, 1130.
Illinoian drift, Quaternary, Illinois: Udden, 1117.
Iowa terrane, Quaternary, Iowa: Keyes, 577.
Independence terrane, Devonian, Iowa: Keyes, 577.
Indian Ladder beds, Ordovician, New York: Hartnagel, 432.
Inwood limestone, pre-Cambrian, New York: Hartnagel, 432.
Iowa terrane, Quaternary, Iowa: Keyes, 577.
Iowan drift, Quaternary, Iowa: Norton *et al.*, 800.
Irasburg conglomerate, Ordovician, Vermont: Richardson, 904; Richardson and Collister, 905; Richardson and Conway, 906.
Irondequoit limestone, Silurian, New York: Hartnagel, 432.
Ithaca beds, Devonian, New York: Hartnagel, 432.
Jacalitos division, Miocene, California: Dumble, 293.
Jameco formation, Quaternary, New York: Hartnagel, 432.
James River formation, upper Cambrian, Nova Scotia: Williams, 1211.
Jefferson limestone, Devonian, Idaho and Utah: Richards and Mansfield, 903.
Jefferson limestone, Devonian, Montana: Calvert, 159.
Jefferson City formation, Cambrian, Missouri: Crane, 233.
Jennings formation, Devonian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Joachim formation, Ordovician, Missouri: Crane, 233.
John Day, Oligocene and Miocene, Oregon: Osborn, 815.
Jollytown sandstone, Carboniferous, West Virginia: Hennen, 447.
Jordan sandstone, Cambrian, Iowa: Norton *et al.*, 800.
Jordon terrane, Cambrian, Iowa: Keyes, 577.
Jualin diorite, Cretaceous, Alaska: Knopf, 595.
Judith River formation, Cretaceous, Montana: Pepperberg, 842.
Judith River formation, Tertiary (Eocene), Montana: Peale, 837.
Julianehaab granite, Algonkian, Greenland: Ussing, 1130.
Juniata formation, Ordovician, West Virginia: Stose and Swartz, 1058.
Kagawong beds, Ordovician, Ontario: Foerste, 329.
Kalkberg limestone, Devonian, New York: Hartnagel, 432.
Kamishak chert, Triassic, Alaska: Martin and Katz, 721.
Kamouraska formation, Cambrian, Quebec: Dresser, 288.
Kanouse sandstone, Devonian, New Jersey: Clarke, 198.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Kanouse sandstone, Devonian, New York: Hartnagel, 432.
Kansan drift, Quaternary, South Dakota: Shimek, 976.
Kansas terrane, Quaternary, Iowa: Keyes, 577.
Kansas City limestone, Pennsylvanian, Missouri: Hinds, 470.
Keefer sandstone member, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Keewatin, pre-Cambrian, Ontario: Burrows, 137; Collins, 218; Lawson, 637; Moore, 780.
Keewatin, pre-Cambrian, Ontario and Quebec: Wilson, 1220.
Keewatin, pre-Cambrian, Quebec: Bancroft, 43.
Keewatin greenstones, pre-Cambrian, Minnesota, Zapffe, 1260.
Keewatin rocks, pre-Cambrian, Michigan: Lane, 627.
Keewatin series, pre-Cambrian, Ontario: Hopkins, 491; McMillan, 709.
Keokuk formation, Mississippian, Missouri: Crane, 233.
Keokuk limestone, Mississippian, Illinois: Lines, 670.
Keokuk terrane, Carboniferous, Iowa: Keyes, 577.
Ketona dolomite, Alabama: Butts, 148.
Kettle River formation, Oligocene?, British Columbia: Drysdale, 289.
Kettle River formation, Tertiary, British Columbia: LeRoy, 655.
Keweenaw series, Cambrian, Michigan: Lane, 627.
Keweenawan, pre-Cambrian, Ontario, Moore, 780.
Keweenawan rocks, Cambrian, Michigan: Lane, 627.
Keweenawan rocks, pre-Cambrian, Minnesota: Zapffe, 1260.
Kilbuck conglomerate, Mississippian, New York: Hartnagel, 432.
Kimmswick formation, Ordovician, Missouri: Crane, 233.
Kinderhook beds, Mississippian, Illinois: Lines, 670.
Kinderhook group, Mississippian, Iowa: Norton *et al.*, 800.
Kinderhook shale, Mississippian, Illinois: Udden, 1117.
Kirkfield limestone, Ordovician, Ontario: Johnston, 557.
Kirkwood formation, Quaternary, New York: Hartnagel, 432.
Kitchener formation, Cambrian, British Columbia: Schofield, 953.
Klusha intrusives, Tertiary or Pleistocene, Yukon: Cairnes, 149.
Knapp beds, Mississippian, New York: Hartnagel, 432.
Knight formation, Tertiary, Wyoming: Sinclair and Granger, 985.
Knob Hill group, Paleozoic, British Columbia: LeRoy, 655.
Knobstone formation, Indiana: Cumings, 244.
Knox dolomite, Cambro-Ordovician, Georgia: Maynard, 738.
Knox dolomite, Ordovician, Tennessee: Gordon and Jarvis, 383.
Knoydart formation, Devonian, Nova Scotia: Williams, 1211.
Kootanie formation, Cretaceous, Alberta: Dowling, 285.
Kootenai formation, Cretaceous, Montana: Calvert, 158, 159.
Kootenay formation, Cretaceous, Alberta: Leach, 643.
Kummer series, Eocene, Washington: Evans, 313.
Laberge series, Jurassic-Cretaceous, Yukon: Cairnes, 149.
Labette shale, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Ladentown diabase, Jura-Trias, New York: Hartnagel, 432.
Lafayette formation, Pliocene, Kentucky: Glenn, 373.
Lafayette formation, Pliocene?, North Carolina: Clark *et al.*, 193.
Lafayette formation, Pliocene?, Virginia: Clark and Miller, 192.
LaFayette group, Tertiary, Missouri: Crane, 233.
LaGrange group, Tertiary, Missouri: Crane, 233.
Lake Shore traps, Cambrian, Michigan: Lane, 627.
Lakota sandstone, Cretaceous, Wyoming-South Dakota: Stone, 1045.
Lamotte formation, Cambrian, Missouri: Crane, 233.
Lance formation, Wyoming: Winchester, 1231.
Lance formation, Cretaceous or Tertiary, Montana: Beekly, 63; Calvert, 157; Herald, 448.
Lance formation, Cretaceous or Tertiary, North Dakota: Leonard, 654.
Lance formation, Cretaceous or Tertiary, Wyoming: Wegemann, 1179.
Langston limestone, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
Lansdale member, Triassic, Pennsylvania: Wherry, 1191.
Lansing formation, Pennsylvanian, Missouri: Hinds, 470.
Laona sandstone, Devonian, New York: Hartnagel, 432.
La Plata sandstone, Jurassic, Utah: Woodruff, 1243.
Laramie formation, Cretaceous, Colorado and New Mexico: Lee, 648.
Laramie formation, Cretaceous, Wyoming: Jamison, 539, 540.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Laramie formation, Cretaceous and Tertiary, Manitoba and Saskatchewan: Ries and Keele, 916.
Larder slates and dolomites, pre-Cambrian, Ontario and Quebec; Wilson, 1220.
LaSalle limestone, Pennsylvanian, Illinois: Lines, 670.
Laughery formation, Ordovician, Indiana: Foerste, 327.
Laurention, pre-Cambrian, New York: Bancroft, 43.
Laurention, pre-Cambrian, Ontario: Burrows, 137; Collins, 218; Lawson, 637; Moore, 780.
Laurentian, pre-Cambrian, Ontario and Quebec: Wilson, 1220.
Laurentian series, pre-Cambrian, Ontario: Hopkins, 491.
Lawrence terrane, Cretaceous, Iowa: Keyes, 577.
Leadville limestone, Carboniferous, Colorado: Patton *et al.*, 834.
LeClaire terrane, Silurian, Iowa: Keyes, 577.
Lee conglomerate, Carboniferous, Kentucky: Dilworth, 284.
Lee formation, Carboniferous, Kentucky: Miller, 756.
Leech River formation, Carboniferous?, British Columbia (Vancouver Island): Clapp, 182; Clapp and Allan, 185.
Lehigh limestone, Ordovician, Pennsylvania: Peck, 839.
Leitchfield formation, Mississippian, Kentucky: Glenn, 373.
Leithsville formation, Cambrian, Pennsylvania: Peck, 839.
Leithsville shaly limestone, Cambrian, Pennsylvania: Miller, 757.
Lenapah limestone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Lenoir beds, Ordovician, Tennessee: Gordon and Jarvis, 383.
Leray limestone, Ordovician, New York: Hartnagel, 432.
Levis formation, Ordovician, Ontario: Raymond, 888.
Lewis shale, Cretaceous, Colorado and New Mexico: Lee, 648.
Lewis shale, Cretaceous, Wyoming: Jamison, 539.
Lewiston, Silurian, New York: Hartnagel, 432.
Leyden phyllite, Vermont: Hitchcock, 473.
Lime Creek shale, Devonian, Iowa: Norton *et al.*, 800.
Lime Creek shales, Devonian, Iowa: Keyes, 578.
Lime Creek terrane, Devonian, Iowa: Keyes, 577.
Lincoln formation, Oligocene, Washington: Weaver, 1169.
L'Islet formation, Cambrian, Quebec: Dresser, 288.
Lisman formation, Pennsylvanian, Kentucky: Glenn, 373.
Listmore formation, Pennsylvanian?, Nova Scotia: Williams, 1211.
Little Falls dolomite, Cambrian, New York: Hartnagel, 432.
Little Pine Ridge sandstone, Cretaceous, Wyoming: Jamison, 540.
Livingston conglomerate, Carboniferous, Kentucky: Miller, 756.
Livingston formation, Cretaceous, Montana: Calvert, 158.
Lloyd sand, Cretaceous, New York: Hartnagel, 432.
Lockatong formation, Triassic, New Jersey: Wherry, 1191.
Lockhart formation, Mississippian, Kentucky: Glenn, 373.
Lockport dolomite, Silurian, New York: Hartnagel, 432.
Logan formation, Mississippian, Kentucky: Phalen, 850.
Logan formation, Mississippian, Ohio: Hyde, 528.
Logan sills, pre-Cambrian, Minnesota: Zapffe, 1260.
Long Beards Riffs sandstone, Devonian, New York: Hartnagel, 432.
Longwood shale, Silurian, New York: Hartnagel, 432.
Lookout formation, Pennsylvanian, Georgia: Maynard, 738.
Lorraine, Ordovician, New York: Hartnagel, 432.
Lorraine shale, Ordovician, Pennsylvania: Ziegler, 1262.
Lost Cabin formation, Eocene, Wyoming: Osborn, 815.
Lost Cabin formation, Tertiary, Wyoming: Sinclair and Granger, 985.
Louisiana limestone, Carboniferous, Iowa, Missouri: Keyes, 578.
Louisiana limestone, Mississippian, Missouri: Crane, 233.
Louisiana terrane, Carboniferous, Iowa: Keyes, 577.
Lower Magnesian limestone, Ordovician, Illinois: Lines, 670.
Lowerre quartzite, pre-Cambrian, New York: Hartnagel, 432.
Lowville, Ordovician, Ontario: Foerste, 329.
Lowville beds, Ordovician, Ontario: Johnston, 557.
Lowville formation, Ordovician, Ontario: Raymond, 888.
Lowville limestone, Ordovician, New York: Hartnagel, 432.
Lucas terrane, Devonian, Iowa: Keyes, 577.
Ludlowville shale, Devonian, New York: Hartnagel, 432.
Lykins formation, Carboniferous, Colorado: Girty, 368.
Lysite formation, Eocene, Wyoming: Osborn, 815.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Lysite formation, Tertiary, Wyoming: Sinclair and Granger, 985.
McAdam formation, Silurian, Nova Scotia: Williams, 1211.
McAra's Brook formation, Mississippian, Nova Scotia: Williams, 1211.
McKenzie formation, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
McLeansboro formation, Carboniferous, Illinois: Shaw, 970.
McLeansboro formation, Pennsylvanian, Illinois: Lines, 670.
McLeansboro formation, Pennsylvanian, Illinois: Shaw and Savage, 972.
Madison limestone, Carboniferous (Mississippian), Idaho and Utah: Richards and Mansfield, 903.
Madison limestone, Mississippian, Montana: Calvert, 159.
Madisonville limestone, Carboniferous, Kentucky: Glenn, 371.
Magothy formation, Cretaceous, New York: Hartnagel, 432.
Mahoning sandstone member, Pennsylvanian, Ohio, West Virginia, Kentucky: Phalen, 850.
Malignant Cove formation, Ordovician, Nova Scotia: Williams, 1211.
Mancos shale, Cretaceous, Colorado: Lee, 647, 648.
Mancos shale, Cretaceous, New Mexico: Lee, 646.
Mancos shale, Cretaceous, Utah: Lupton, 689, 690.
Mancos shale, Cretaceous, Wyoming: Woodruff and Winchester, 1246.
Manhattan schist, pre-Cambrian, New York: Hartnagel, 432.
Manitoban, Devonian, Manitoba: Kindle, 584.
Manlius limestone, Devonian, New York: Kindle, 581.
Manlius limestone, Silurian, New York: Hartnagel, 432.
Mannington sandstone, Carboniferous, West Virginia: Hennen, 447.
Mansfield sandstone, Mississippian, Indiana: Cumings, 244.
Maquoketa shale, Ordovician, Illinois: Lines, 670.
Maquoketa shale, Ordovician, Iowa: Norton *et al.*, 800.
Marais des Cygnes terrane, Carboniferous, Iowa: Keyes, 577.
Marble Falls limestone, Pennsylvanian, Texas: Paige, 817.
Marcellus, Devonian, New York: Kindle, 581.
Marcellus black shale, Devonian, New York: Hartnagel, 432.
Marcellus? formation, Devonian, Pennsylvania: Miller, 757.
Marcellus shale, Devonian, Ontario: Stauffer, 1023.
Marcellus shale member, Devonian, West Virginia: Stose and Swartz, 1058.
Marietta sandstone (upper), Carboniferous, West Virginia: Hennen, 447.
Marietta sandstone (lower), Carboniferous, West Virginia: Hennen, 447.
Maroon conglomerate, Pennsylvanian?, Colorado: Lee, 647.
Martinez formation, Eocene, California: Dumble, 293.
Martinsburg shale, Ordovician, Pennsylvania: Peck, 839.
Martinsburg shale, Ordovician, West Virginia: Stose and Swartz, 1058.
Martinsburg shales, Ordovician, Pennsylvania: Miller, 757.
Matawan formation, Cretaceous, New York: Hartnagel, 432.
Matfield shale, Permian, Oklahoma: Ohern and Garrett, 803.
Mauch Chunk formation, Mississippian, Pennsylvania: Munn, 782.
Maury shale, Waverlyan, Tennessee: Ulrich, 1122.
Maysville formation, Ordovician, Ohio: Fuller and Clapp, 346.
Maxville limestone, Mississippian, Kentucky: Phalen, 850.
Maxville limestone, Mississippian, Ohio: Hyde, 528.
Mazanilla series, Costa Rica: Romanes, 931.
Meadville limestone, Mississippian, Pennsylvania and Ohio: Prosser, 872.
Medina sandstone, Silurian, New York: Hartnagel, 432.
Meetinghouse Hill slate, Vermont: Hitchcock, 473.
Memphremagog slates, Vermont: Hitchcock, 473.
Menteth limestone, Devonian, New York: Hartnagel, 432.
Mesaverde formation, Cretaceous, Colorado: Lee, 647.
Mesaverde formation, Cretaceous, Colorado and New Mexico: Lee, 648.
Mesaverde formation, Cretaceous, New Mexico: Lee, 646.
Mesaverde formation, Cretaceous, Utah: Lupton, 690.
Mesaverde formation, Cretaceous, Wyoming: Jamison, 539; Woodruff and Winchester, 1246.
Metchosin volcanics, Jurassic?, British Columbia (Vancouver Island): Clapp, 182; Clapp and Allan, 185.
Middlesex shale, Devonian, New York: Hartnagel, 432.
Midway volcanic group, Miocene?, British Columbia: Drysdale, 289; LeRoy, 655.
Million member, Ordovician, Kentucky: Foerste, 327.
Millstone grit group, Carboniferous, New Brunswick: Young, 1259.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Millstream series, Ordovician, New Brunswick: Young, 1258.
Mississippian group, Carboniferous: Hartnagel, 432.
Mississippian series, Carboniferous, Illinois: Shaw, 970.
Missouri group, Pennsylvanian, Iowa: Norton *et al.*, 800.
Missouri group, Pennsylvanian, Missouri: Hinds, 470.
Missouri series, Pennsylvanian, Missouri: Crane, 233.
Moencopie formation, Permian(?), Utah: Woodruff, 1243.
Mohawkian group, Ordovician, New York: Hartnagel, 432.
Monmouth formation, Cretaceous, New York: Hartnagel, 432.
Monongahela formation, Pennsylvanian, Pennsylvania: Munn, 782.
Monongahela formation, Pennsylvanian, West Virginia: Phalen, 850.
Monongahela series, Carboniferous, West Virginia: Hennen, 447.
Monroe Creek, Oligocene, Nebraska: Osborn, 815.
Monroe formation, Silurian, Ohio: Stauffer, 1025.
Montana group, Cretaceous, Montana: Calvert, 158, 159.
Montana group, Cretaceous, Wyoming: Wegemann, 1179.
Montecello terrane, Silurian, Iowa: Keyes, 577.
Monterey division, Miocene, California: Dumble, 293.
Monterey series, Neocene, California: Clark, 188.
Monterey series, Tertiary, California: Martin, 718.
Montesano formation, Miocene, Washington: Weaver, 1169.
Montrose chert, Carboniferous, Iowa: Van Tuyl, 1138.
Monument Creek group, Tertiary, Colorado: Richardson, 908, 909.
Morgantown sandstone, Carboniferous, West Virginia: Hennen, 447.
Morgantown (?) sandstone member, Pennsylvanian, Ohio, West Virginia, Kentucky: Phalen, 850.
Morrison (?) formation, Cretaceous or Jurassic, Montana: Calvert, 159.
Morrison formation, Cretaceous, New Mexico: Lee, 646.
Morrison formation, Lower Cretaceous or Jurassic, Colorado: Stose, 1056.
Morrison formation, Jurassic, Wyoming: Jamison, 539, 540; Wegemann, 1178.
Morrison shale, Jurassic or Cretaceous, Wyoming-South Dakota: Stone, 1045.
Moscow shale, Devonian, New York: Hartnagel, 432.
Mosheim limestone, Ordovician, Tennessee: Gordon and Jarvis, 383.
Mount Morris limestone, Carboniferous, West Virginia: Hennan, 447.
Mount Stevens group, Paleozoic, Yukon: Cairnes, 149.
Mt. Whyte formation, Cambrian, British Columbia: Allan, 9.
Mowry beds, Cretaceous, Wyoming: Jamison, 540.
Mowry shale member, Cretaceous, Wyoming: Wegemann, 1178.
Moydart formation, Silurian, Nova Scotia: Williams, 1211.
Moyie formation, Cambrian, British Columbia: Schofield, 953.
Mulford formation, Pennsylvanian, Kentucky: Glenn, 373.
Murphy marble, Cambrian, Georgia: Maynard, 738.
Myers shale, Carboniferous, West Virginia: Stose and Swartz, 1058.
Naknek formation, Jurassic, Alaska: Martin and Katz, 721.
Nanaimo series, Cretaceous, British Columbia: Clapp, 183.
Nanjemoy formation, Eocene, Maryland: Miller, 758.
Nanjemoy formation, Eocene, Virginia: Clark and Miller, 192.
Naples beds, Devonian, New York: Hartnagel, 432.
Nass formation, British Columbia: McConnell, 695, 696.
Nazareth limestone, Ordovician, Pennsylvania: Miller, 757; Peck, 839.
Nebraska terrane, Quaternary, Iowa: Keyes, 577.
Nebraskan drift, Quaternary, South Dakota: Shimek, 976.
Neelytown limestone, Cambrian, New York: Hartnagel, 432.
Nelson batholith, Jurassic?, British Columbia: LeRoy, 656.
Nenana gravel, Tertiary, Alaska: Capps, 170.
New Albany black shale, Indiana: Cumings, 244.
Newark group, Triassic, North Carolina: Stone, 1046.
Newark group, Triassic, Pennsylvania: Wherry, 1191.
Newark series, Jura-Trias, New York: Hartnagel, 432.
Newark series, Triassic, Pennsylvania: Eaton, 303.
Newcastle formation, Cretaceous, British Columbia: Clapp, 183.
Newfoundland grit, Devonian, New York: Clarke, 198.
Newman limestone, Carboniferous, Kentucky: Miller, 756.
New Providence shale, Indiana: Cumings, 244.
New Richmond terrane, Cambrian, Iowa: Keyes, 577.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

New Scotland formation, Devonian, Illinois: Lines, 670.
New Scotland limestone, Devonian, New York: Hartnagel, 432; Kindle, 581.
Niagara dolomite, Silurian, Iowa: Norton *et al.*, 800.
Niagara formation, Silurian, Missouri: Crane, 233.
Niagara limestone, Silurian, Illinois: Udden, 1117.
Niagara limestone, Silurian, Ohio: Fuller and Clapp, 346.
Niagaran group, Silurian, New York: Hartnagel, 432.
Nicola series, Triassic and Jurassic?, British Columbia: Daly, 254.
Nicoyan series, Miocene, Costa Rica: Romanes, 932.
Nineveh limestone member, Permian, Pennsylvania: Munn, 782.
Nineveh sandstone, Carboniferous, West Virginia: Hennen, 447.
Niobrara formation, Cretaceous, Kansas: Parker, 826.
Niobrara formation, Cretaceous, Manitoba: Ries and Keele, 916.
Niobrara formation, Cretaceous, Wyoming: Jamison, 540.
Niobrara shale, Cretaceous, Wyoming: Wegemann, 1178.
Niobrara terrane, Cretaceous, Iowa: Keyes, 577.
Nipisiguit granite, Devonian?, New Brunswick: Young, 1258.
Nipissing diabase, pre-Cambrian, Quebec: Wilson, 1221.
Nisconlith series, pre-Cambrian, British Columbia: Daly, 255.
Nishnabotna terrane, Cretaceous, Iowa: Keyes, 577.
Nisky limestone, Ordovician, Pennsylvania: Miller, 757.
Nitinat formation, Jurassic or Triassic?, British Columbia (Vancouver Island): Clapp, 182; Clapp and Allan, 185.
Nonesuch formation, pre-Cambrian, Wisconsin: Thwaites, 1085.
Nonesuch shales, Cambrian, Michigan, Michigan: Lane, 627.
Normanskill shale, Ordovician, New York: Hartnagel, 432.
Norristown formation, Triassic, Pennsylvania: Wherry, 1191.
Northumberland formation, Cretaceous, British Columbia: Clapp, 183.
Nounan limestone, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
Nowata shale, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Nugget sandstone, Jurassic or Triassic, Idaho and Utah: Richards and Mansfield, 903.
Nugget sandstone, Triassic or Jurassic, Utah: Boutwell, 92.
Nunda sandstone, Devonian, New York: Hartnagel, 432.
Nussbaum formation, Pliocene (?), Colorado: Stose, 1056.
Ohio Creek conglomerate, Eocene, Colorado: Lee, 647.
Ohio shale, Devonian, Illinois: Lines, 670.
Ohio shale, Devonian, Ohio: Hyde, 528; Prosser, 872; Stauffer, 1025.
Ohio shale group, Devonian, Ohio: Kindle, 581.
Olean conglomerate, Pennsylvanian, New York: Hartnagel, 432.
Olentangy shales, Devonian, Ohio: Kindle, 581; Stauffer, 1025.
Oljato sandstone member, Permian, Utah: Woodruff, 1243.
Olmsted shale, Ohio: Cushing, 246.
Olmsted shale, Devonian, Ohio: Kindle, 581.
Olmsted shale, Waverlyan, Ohio: Ulrich, 1122.
Oneida conglomerate, Silurian, New York: Hartnagel, 432.
Oneonta sandstone, Devonian, New York: Hartnagel, 432.
Oneota terrane, Cambrian, Iowa: Keyes, 577.
Onondaga, Devonian, New York: Kindle, 581.
Onondaga formation, Devonian, Missouri: Crane, 233.
Onondaga limestone, Devonian, Illinois: Lines, 670.
Onondaga limestone, Devonian, New York: Hartnagel, 432.
Onondaga limestone, Devonian, Ontario: Stauffer, 1023, 1024.
Onondaga shale member, Devonian, West Virginia: Stose and Swartz, 1058.
Onondaga shale member of Romney formation, Devonian, Maryland, West Virginia, and Virginia: Kindle, 581.
Onondagan series, Devonian, Pennsylvania: Miller, 757.
Ontarian system, pre-Cambrian, Ontario: Lawson, 637.
Ontaric or Siluric system: Hartnagel, 432.
Orange group, Cretaceous?, Alaska and Yukon: Cairnes, 154.
Orange group, Mesozoic (probably Cretaceous), Alaska and Yukon: Cairnes, 150.
Orangeville formation, Mississippian, Ohio: Prosser, 872.
Orangeville shale, Ohio: Cushing, 246.
Oread limestone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Oregonia division, Ordovician, Ohio and Kentucky: Foerste, 328.
Orienta sandstone, pre-Cambrian, Wisconsin: Thwaites, 1085.
Orindan, Neocene, California: Clark, 188.
Oriskanian group, Devonian: Hartnagel, 432.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Oriskany, Devonian, New York: Kindle, 581.
Oriskany formation, Devonian, Pennsylvania: Miller, 757.
Oriskany sandstone, Devonian, New York: Hartnagel, 432.
Oriskany sandstone, Devonian, Ontario: Stauffer, 1023, 1024.
Oriskany sandstone, Devonian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Oro Grande series, California: Hershey, 452.
Oronto group, pre-Cambrian, Wisconsin: Thwaites, 1085.
Osage group, Mississippian, Iowa: Norton *et al.*, 800.
Osage series, Carboniferous, Iowa: Van Tuyl, 1138.
Oswayo beds, Mississippian, New York: Hartnagel, 432.
Oswegan group, Silurian: Hartnagel, 432.
Oswego sandstone, Silurian, New York: Hartnagel, 432.
Otis terrane, Devonian, Iowa: Keyes, 577.
Otselic sands and shales, Devonian, New York: Hartnagel, 432.
Ottawa gneiss, pre-Cambrian, Quebec: Stansfield, 1018.
Ottertail formation, Cambrian, British Columbia: Allan, 9; Walcott, 1146.
Outer conglomerate, pre-Cambrian, Wisconsin: Thwaites, 1085.
Outer Copper Harbor conglomerate, Cambrian, Michigan: Lane, 627.
Oxmoor sandstone, Mississippian, Georgia: Maynard, 738.
Paget formation, Cambrian, British Columbia: Allan, 9.
Paint Lick member, Ordovician, Kentucky: Foerste, 327.
Palisade diabase, Jura-Trias, New York: Hartnagel, 432.
Pamelia formation, Ordovician, Ontario: Raymond, 888.
Pamelia limestone, Ordovician, New York: Hartnagel, 432.
Pamlico formation, Pleistocene, North Carolina: Clark *et al.*, 193.
Pamunkey group, Eocene, Maryland: Miller, 758.
Pamunkey group, Eocene, Virginia: Clark and Miller, 192.
Panamo conglomerate, Mississippian, New York: Hartnagel, 432.
Paonia shale member, Cretaceous, Colorado: Lee, 647.
Papagallos shales, Cretaceous, Mexico: Dumble, 294.
Park City formation, Carboniferous, Utah: Boutwell, 92.
Parkhead sandstone member, Devonian, West Virginia: Stose and Swartz, 1058.
Parkman member, Cretaceous, Wyoming: Jamison, 540.
Parkville terrane, Cretaceous, Iowa: Keyes, 577.
Parrish limestone, Devonian, New York: Hartnagel, 432.
Pasayton formation, Lower Cretaceous, British Columbia: Camsell, 164.
Paspotansa marl member, Eocene, Maryland: Miller, 758.
Paspotansa marl member, Eocene, Virginia: Clark and Miller, 192.
Patapsco formation, Cretaceous, Virginia: Berry, 67.
Patapsco formation, Lower Cretaceous, Virginia: Clark and Miller, 192.
Patuxent formation, Cretaceous, North Carolina: Clark *et al.*, 193.
Patuxent formation, Cretaceous, Virginia: Berry, 67.
Patuxent formation, Lower Cretaceous, Virginia: Clark and Miller, 192.
Pawnee limestone, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Pearl Harbor series, Pliocene, Hawaiian Islands: Hitchcock, 474.
Pearl Harbor series, Tertiary, Hawaii: Hitchcock, 472.
Peedee sand, Cretaceous, North Carolina: Clark *et al.*, 193.
Peekskill granite, pre-Cambrian, New York: Hartnagel, 432.
Pelona schists, California and Oregon: Hershey, 452.
Pend d'Oreille group, Carboniferous?, British Columbia: LeRoy, 656.
Pennington shale, Carboniferous, Kentucky: Miller, 756.
Pennsylvanian group, Carboniferous: Hartnagel, 432.
Pennsylvanian series, Carboniferous, Illinois: Shaw, 970.
Pennsylvanian series, Illinois: Udden, 1117.
Pensauken formation, Quaternary, New York: Hartnagel, 432.
Peoria terrane, Quaternary, Iowa: Keyes, 577.
Perkasie member, Triassic, Pennsylvania: Wherry, 1191.
Perkins group, Paleozoic, Yukon: Cairnes, 149.
Perryville member, Ordovician, Kentucky: Foerste, 327.
Phosphoria formation, Carboniferous (Permian?), Idaho and Utah: Richards and Mansfield, 903.
Pickering gneiss, pre-Cambrian, Pennsylvania: Miller, 759.
Pictured Cliffs sandstone, Cretaceous, Colorado and New Mexico: Lee, 648.
Pierre formation, Cretaceous, Manitoba: Ries and Keele, 916.
Pierre formation, Cretaceous, Wyoming: Jamison, 540; Wegemann, 1178, 1179.
Pierre shale, Cretaceous, Kansas: Parker, 826.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Pierre shale, Cretaceous, Montana: Beekly, 63; Calvert, 157.
Pierre shale, Cretaceous, South Dakota: Perisho and Visher, 843.
Pinkerton sandstone, Carboniferous, West Virginia: Stose and Swartz, 1058.
Pinole tuff, Neocene, California: Clark, 188.
Piscataway member, Eocene, Maryland: Miller, 758.
Piscataway marl member, Eocene, Virginia: Clark and Miller, 192.
Pit shales, Triassic, California: Smith, 995.
Pitkin limestone, Mississippian, Oklahoma: Snider, 1005.
Pittsburgh limestone (upper), Carboniferous, West Virginia: Hennen, 447.
Pittsburgh limestone (lower), Carboniferous, West Virginia: Hennen, 447.
Pittsburgh red shale, Carboniferous, West Virginia: Hennen, 447.
Pittsburgh sandstone (lower), Carbonifous, West Virginia: Hennen, 447.
Pittsburgh sandstone member, Pennsylvanian, Pennsylvania: Munn, 782.
Pittsford shale, Silurian, New York: Hartnagel, 432.
Platte terrane, Cretaceous, Iowa: Keyes, 577.
Platteville limestone, Ordovician, Illinois: Lines, 670.
Platteville limestone, Ordovician, Iowa: Norton *et al.*, 800.
Platteville terrane, Ordovician, Iowa: Keyes, 577.
Plattin formation, Ordovician, Missouri: Crane, 233.
Plattsmouth terrane, Cretaceous, Iowa: Keyes, 577.
Pleasonton formation, Pennsylvanian, Missouri: Crane, 233.
Pleasonton shale, Pennsylvanian, Missouri: Hinds, 470.
Plum Point marl member, Miocene, Maryland: Miller, 758.
Pochuck gneiss, pre-Cambrian, New York: Hartnagel, 432.
Pocomo formation, Mississippian, Pennsylvania: Munn, 782.
Pohenagamuk formation, Ordovician, Quebec: Dresser, 288.
Point Pleasant formation, Ordovician, Ohio: Fuller and Clapp, 346.
Pokegama quartzite, pre-Cambrian, Minnesota: Van Barneveld, 1133.
Ponca terrane, Cretaceous, Iowa: Keyes, 577.
Pontiac group, pre-Cambrian, Quebec: Wilson, 1221.
Pontiac schist, pre-Cambrian, Ontario and Quebec: Wilson, 1220.
Porcupine group, Ordovician - Silurian, Alaska and Yukon: Cairnes, 150.
Portage beds, Devonian, New York: Hartnagel, 432.
Port Ewen beds, Devonian, New York: Hartnagel, 432.
Port Jervis limestone, Devonian, New York: Hartnagel, 432.
Porter shales, Miocene, Washington: Weaver, 1169.
Porters Creek group, Tertiary, Missouri: Crane, 233.
Potapaco clay member, Eocene, Maryland: Miller, 758.
Potapaco clay member, Eocene, Virginia: Clark and Miller, 192.
Potomac group, Cretaceous, Virginia: Berry, 67.
Potosi dolomite, Alabama: Butts, 148.
Potosi formation, Cambrian, Missouri: Crane, 233.
Potsdam formation, Cambrian, Pennsylvania: Eaton, 303.
Potsdam sandstone, Cambrian, New York: Hartnagel, 432.
Potsdam sandstone, Ordovician, Quebec: Valiquette, 1132.
Pottstown member, Triassic, Pennsylvania: Wherry, 1191.
Pottsville formation, Carboniferous, Alabama: Munn, 786.
Pottsville formation, Pennsylvanian, Illinois: Lines, 670.
Pottsville formation, Pennsylvanian, Kentucky: Phalen, 850.
Pottsville formation, Pennsylvanian, Pennsylvania: Munn, 782.
Pottsville sandstone, Carboniferous, Illinois: Shaw, 970.
Pottsville sandstone, Pennsylvanian, Illinois: Shaw and Savage, 972.
Poughquag quartzite, Cambrian, New York: Hartnagel, 432.
Poxino Island shale, Silurian, New York: Hartnagel, 432.
Prairie du Chien group, Ordovician, Iowa: Norton *et al.*, 800.
Prattsburg sandstone, Devonian, New York: Hartnagel, 432.
Price sandstone, Mississippian, Virginia: Branson, 103.
Prichard formation, pre-Cambrian: Hershey, 452.
Prichard formation, pre-Cambrian, Idaho: Huston, 527.
Proctor formation, Cambrian, Missouri: Crane, 233.
Proctor sandstones, Carboniferous, West Virginia: Hennen, 447.
Prosperity limestone member, Permian, Pennsylvania: Munn, 782.
Protection formation, Cretaceous, British Columbia: Clapp, 183.
Puerco formation, Tertiary, New Mexico: Lee, 648.
Puerticitos limestone, Tertiary, Mexico: Lee, 650.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Puget formation, Eocene, Washington: Evans, 313; Weaver, 1169.
Pulaski shale, Mississippian, Virginia: Branson, 103.
Pulaski shale, Ordovician, New York: Hartnagel, 432.
Punta de la Mesa sandstone member, Cretaceous, New Mexico: Lee, 648.
Purcell series, Cambrian?, British Columbia: Schofield, 953.
Purgatoire formation, Lower Cretaceous, Colorado: Stose, 1056.
Purslane sandstone, Carboniferous, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Quadrant formation, Carboniferous, Montana: Calvert, 159.
Quebec City formation, Ordovician, Ontario: Raymond, 888.
Queenston, Silurian, New York: Hartnagel, 432.
Queenstown shales, Ordovician, Ontario: Foerste, 329.
Ralston formation, Eocene, Wyoming: Osborn, 815.
Rapid terrane, Devonian, Iowa: Keyes, 577.
Raquet series, Carboniferous, Alaska and Yukon: Cairnes, 150.
Raritan formation, Cretaceous, New York: Hartnagel, 432.
Ravenswood granodiorite, pre-Cambrian, New York: Hartnagel, 432.
Rawhide formation, Carboniferous, British Columbia: LeRoy, 655.
Redstone limestone member, Pennsylvanian, Pennsylvania: Munn, 782.
Reese formation, Tertiary, Montana: Calvert, 159.
Rensselaer grit, Devonian, New York: Hartnagel, 432.
Revett formation, pre-Cambrian, Idaho: Hershey, 452.
Rex Chert member, Carboniferous, Idaho and Utah: Richards and Mansfield, 903.
Rhinestreet shale, Devonian, New York: Hartnagel, 432.
Richmond formation, Ordovician, Illinois: Lines, 670.
Richmond formation, Ordovician, Ohio: Fuller and Clapp, 346.
Ripley formation, Cretaceous, Illinois: Lines, 670.
Riverside sandstone, Indiana: Cumings, 244.
Riverside terrane, Tertiary, Iowa: Keyes, 577.
Rochdale group, Cambrian, New York: Hartnagel, 432.
Roche Miette limestone, Devonian, Alberta: Dowling, 285.
Rochester shale, Silurian, New York: Hartnagel, 432.
Rockcastle series, Carboniferous, Kentucky: Miller, 756.
Rockmart shales and slates, Ordovician, Georgia: Maynard, 738.
Rockport limestones, Carboniferous, West Virginia: Hennen, 447.
Rockwell formation, Carboniferous, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Rockwood formation, Silurian, Tennessee: Maynard, 738.
Rockwood formation, Silurian, Tennessee: Gordon and Jarvis, 383.
Rogers Gap division, Ordovician, Kentucky: Foerste, 327.
Rollins sandstone, Cretaceous, Colorado: Lee, 647.
Rome formation, Cambrian, Georgia: Maynard, 738.
Rome formation, Cambrian, Tennessee: Gordon and Jarvis, 383.
Romney shale, Devonian, West Virginia and Maryland: Kindle, 581.
Romney shale, Devonian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Rondout waterlime, Silurian, New York: Hartnagel, 432.
Rosamond series: Tertiary, California: Baker, 39.
Rosebud, Oligocene and Miocene, South Dakota: Osborn, 815.
Rosebud formation, Tertiary, South Dakota: Perisho and Visher, 843.
Rosendale waterlime, Silurian, New York: Hartnagel, 432.
Roslyn formation, Eocene, Washington: Weaver, 1169.
Ross Brook formation, Silurian, Nova Scotia: Williams, 1211.
Rossland volcanic group, Carboniferous or post-Carboniferous, British Columbia: LeRoy, 656.
Roubidoux formation, Cambrian, Missouri: Crane, 233.
Royalton formation, Mississippian, Ohio: Prosser, 872.
Rush Run sandstone, Carboniferous, West Virginia: Hennen, 447.
Ruth limestone, Nevada: Hershey, 452.
Rysedorph conglomerate, Ordovician, New York: Hartnagel, 432.
Saanich granodiorite, British Columbia (Vancouver Island): Clapp, 182.
Saanich granodiorite, Jurassic and Cretaceous?, British Columbia: Clapp and Allan, 185.
Sabula terrane, Silurian, Iowa: Keyes, 577.
Saclin formation, Quaternary, Nicaragua: Hershey, 450.
Sagamore sandstone lentil, Devonian, Ohio: Prosser, 872.
St. Charles limestone, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
St. Clair marble, Silurian, Oklahoma: Snider, 1005.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

St. Croixan or Upper Cambrian: Walcott, 1149.
Ste. Genevieve formation, Mississippian, Missouri: Crane, 233.
Ste. Genevieve limestone, Mississippian, Illinois: Lines, 670.
St. Lawrence formation, Cambrian, Iowa: Norton *et al.*, 800.
St. Lawrence terrane, Cambrian, Iowa: Keyes, 577.
St. Louis group, Mississippian, Missouri: Crane, 233.
St. Louis limestone, Mississippian, Illinois: Lines, 670.
St. Louis terrane, Carboniferous, Iowa: Keyes, 577.
St. Marys formation, Miocene, Maryland: Clark and Miller, 192.
St. Marys formation, Miocene, North Carolina: Clark *et al.*, 193.
St. Peter sandstone, Ordovician, Illinois: Lines, 670; Udden, 1117.
St. Peter sandstone, Ordovician, Iowa: Norton *et al.*, 800.
St. Peter sandstone, Ordovician, Missouri: Crane, 233.
St. Peter sandstone, Ordovician, Ohio: Fuller and Clapp, 346.
St. Peter terrane, Ordovician, Iowa: Keyes, 577.
St. Piran formation, Cambrian, British Columbia: Allan, 9.
St. Regis formation, pre-Cambrian, Idaho: Hershey, 452.
Salamanca conglomerate, Mississippian, New York: Hartnagel, 432.
Salem limestone, Carboniferous, Iowa: Van Tuyl, 1138.
Salem limestone, Mississippian, Illinois: Lines, 670.
Salem limestone, Mississippian, Iowa: Van Tuyl, 1136.
Salina beds, Silurian, New York: Hartnagel, 432.
Salina (?) formation, Silurian, Iowa: Norton *et al.*, 800.
Salmon hornblende schist, Oregon and California: Hershey, 452.
Saltsburgh sandstone, Carboniferous, West Virginia: Hennen, 447.
San Fernando clays, Tertiary, Mexico: Dumble, 294.
Sangamon stage, Quaternary, Indiana: Shannon, 966.
Sangamon terrane, Quaternary, Iowa: Keyes, 577.
San Juan epoch, Quaternary, Colorado: Atwood and Mather, 32.
San Juan glacial epoch, Quaternary, Colorado: Atwood and Mather, 32.
Sankaty formation, Quaternary, New York: Hartnagel, 432.
San Miguel limestone, Tertiary?, Costa Rica: Romanes, 931.
San Pablo series, Neocene, California: Clark, 188.
Santa Margarita division, Miocene, California: Dumble, 293.
Saranac gneiss, pre-Cambrian, New York: Hartnagel, 432.
Saratogan group, Cambrian, New York: Hartnagel, 432.
Saverton shales, Carboniferous, Iowa, Missouri: Keyes, 578.
Saverton terrane, Carboniferous, Iowa: Keyes, 577.
Schaghticoke shale, Ordovician, New York: Hartnagel, 432.
Schnectady beds, Ordovician, New York: Hartnagel, 432.
Schoharie grit, Devonian, New York: Hartnagel, 432; Kindle, 581.
Seine series, pre-Cambrian, Ontario: Lawson, 636, 637.
Selinsgrove limestone and shale, Devonian, Pennsylvania: Kindle, 581.
Selkirk series, pre-Cambrian and Cambrian, British Columbia: Daly, 254.
Senecan group, Devonian, New York: Hartnagel, 432.
Sergeant terrane, Cretaceous, Iowa: Keyes, 577.
Sevier shales, Ordovician, Tennessee: Gordon and Jarvis, 383.
Sewickley limestone, Carboniferous, West Virginia: Hennen, 447.
Sewickley sandstone (upper), Carboniferous, West Virginia: Hennen, 447.
Sewickley sandstone (lower), Carboniferous, West Virginia: Hennen, 447.
Sewickley sandstone member, Pennsylvanian, Pennsylvania: Munn, 782.
Shakopee terrane, Cambrian, Iowa: Keyes, 577.
Shannon sandstone, Cretaceous, Wyoming: Jamison, 540.
Sharon conglomerate, Mississippian, Ohio: Prosser, 872.
Sharon conglomerate member, Pennsylvanian, Kentucky: Phalen, 850.
Sharon shale, Pennsylvanian, New York: Hartnagel, 432.
Sharpsville sandstone, Mississippian, Ohio: Prosser, 872.
Shawangunk conglomerate, Silurian, New York: Hartnagel, 432.
Shawangunk formation, Silurian, Pennsylvania: Miller, 757.
Shawangunk grit, Silurian, Pennsylvania: Peck, 839.
Shawnee formation, Pennsylvanian, Missouri: Hinds, 470.
Sheguindah beds, Ordovician, Ontario: Foerste, 329.
Shelby (upper) dolomite, Silurian, New York: Hartnagel, 432.
Shelby (lower) dolomite, Silurian, New York: Hartnagel, 432.

Shenango sandstone, Mississippian, Pennsylvania: Prosser, 872.
Sherbrooke formation, British Columbia: Burling, 135.
Sherbrooke formation, Cambrian, British Columbia: Allan, 9.
Sherburne flags, Devonian, New York: Hartnagel, 432.
Short Creek oolite member, Mississippian, Oklahoma: Snider, 1005.
Shumla sandstone, Devonian, New York: Hartnagel, 432.
Shuswap series, pre-Cambrian, British Columbia: Daly, 254, 255.
Sicamous limestone, pre-Cambrian, British Columbia: Daly, 254.
Sicker series, Jurassic or Triassic, British Columbia (Vancouver Island): Clapp, 182; Clapp and Allan, 185.
Sillery formation, Cambrian, Quebec: Dresser, 288.
Sioux quartzite, Algonkian, Iowa: Norton *et al.*, 800.
Siwash series, British Columbia: Bateman, 57.
Siwash series, Carboniferous, British Columbia: Camsell, 162.
Skaneateles shale, Devonian, New York: Hartnagel, 432.
Skeena series, Lower Cretaceous, British Columbia: Malloch, 715.
Skunnemunk conglomerate, Devonian, New York: Hartnagel, 432.
Smithwick shale, Pennsylvanian, Texas: Paige, 817.
Snake Hill beds, Ordovician, New York: Clarke, 198; Hartnagel, 432.
Snyder shales, Carboniferous, Iowa, Missouri: Keyes, 578.
Sodus shale, Silurian, New York: Hartnagel, 432.
Solon terrane, Devonian, Iowa: Keyes, 577.
Sooke formation, Oligocene-Miocene, British Columbia: Clapp and Allan, 185.
Sooke formation, Tertiary, British Columbia (Vancouver Island): Clapp, 182.
Sooke gabbro, British Columbia (Vancouver Island): Clapp, 182.
Sooke gabbro group, Jurassic and Cretaceous?, British Columbia: Clapp and Allan, 185.
Soulala formation, Quaternary, Nicaragua: Hershey, 450.
Spearfish formation, Triassic?, Wyoming-South Dakota: Stone, 1045.
Spergen formation, Mississippian, Missouri: Crane, 233.
Spergen terrane, Carboniferous, Iowa: Keyes, 577.
Stafford limestone, Devonian, New York: Hartnagel, 432.
Standish flags and shales, Devonian, New York: Hartnagel, 432.
Stanton terrane, Cretaceous, Iowa: Keyes, 577.
State Quarry limestone, Devonian, Iowa: Norton *et al.*, 800.
Steeprock series, pre-Cambrian, Ontario: Lawson, 636, 637.
Stephen formation, Cambrian, British Columbia: Allan, 9; Walcott, 1152.
Stissing limestone, Cambrian, New York: Hartnagel, 432.
Stockbridge limestone, Taconic Mountains: Keith, 568.
Stockton beds, Juratrias, New York: Hartnagel, 432.
Stockton formation, Triassic, New Jersey: Wherry, 1191.
Stonehouse formation, Silurian, Nova Scotia: Williams, 1211.
Storm King granite, pre-Cambrian, New York: Hartnagel, 432.
Stormville sandstone, Devonian, New York: Hartnagel, 432.
Striped Peak formation, pre-Cambrian, Idaho: Hershey, 452.
Sulphur Springs formation, Devonian, Missouri: Crane, 233.
Sunbury shale, Carboniferous, Ohio: Prosser, 871.
Sunbury shale, Mississippian, Ohio: Hyde, 528; Prosser, 872; Stauffer, 1025.
Sunbury shale, Waverlyan, Ohio: Ulrich, 1122.
Sundance formation, Jurassic, Wyoming: Jamison, 539, 540; Wegemann, 1178.
Sundance formation, Jurassic, Wyoming-South Dakota: Stone, 1045.
Sunderland formation, Pleistocene, North Carolina: Clark *et al.*, 193.
Sunderland formation, Pleistocene, Virginia: Clark and Miller, 192.
Sunset division, Ordovician, Ohio and Kentucky: Foerste, 327, 328.
Sutton formation, Jurassic, British Columbia (Vancouver Island): Clapp, 182.
Sutton formation, Jurassic or Triassic, British Columbia: Clapp and Allan, 185.
Sutton Mountain series, pre-Cambrian, Quebec: Harvie, 433.
Sweetland Creek shale, Devonian, Iowa: Norton *et al.*, 800.
Sweetland Creek shale, Iowa and Illinois: Udden, 1118.
Sweetland shale, Carboniferous, Missouri: Keyes, 578.
Swift Current beds, Ordovician, Ontario: Foerste, 329.
Sylamore sandstone member, Devonian, Oklahoma: Snider, 1005.
Syracuse salt, Silurian, New York: Hartnagel, 432.
Taconic system, Hartnagel, 432.
Talbot formation, Pleistocene, Maryland: Miller, 758.
Talbot formation, Pleistocene, Virginia: Clark and Miller, 192.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

Talon formation, Devonian?, Quebec: Dresser, 288.
Tantalus conglomerates, Jura-Cretaceous: Cairnes, 149.
Tate division, Ordovician, Kentucky: Foerste, 327.
Tate member, Ordovician, Kentucky: Foerste, 327.
Tatman formation, Tertiary, Wyoming: Sinclair and Granger, 985.
Taylor sandstone, Carboniferous, West Virginia: Hennen, 447.
Tejon formation, Eocene, California: Anderson, 15: Dumble, 293.
Tejon formation, Eocene, Washington: Weaver, 1169.
Tellico formation, Ordovician, Tennessee: Gordon and Jarvis, 383.
Temiskaming series, lower Huronian, Ontario: McMillan, 709.
Temiskaming series, pre-Cambrian, Ontario: Burrows, 137; Hopkins, 491.
Tetagouche series, Ordovician, New Brunswick: Young, 1258.
Thayer terrane, Cretaceous, Iowa: Keyes, 577.
Thaynes formation, Triassic, Utah: Boutwell, 92.
Thaynes limestone, Triassic, Idaho and Utah: Richards and Mansfield, 903.
"Thebes sandstone and shale," Ordovician, Illinois: Lines, 670.
Theresa dolomite, Cambrian, New York: Hartnagel, 432.
Thompson River silts, Pleistocene, British Columbia: Daly, 254.
Threeforks shale, Devonian, Montana: Calvert, 159.
Tichenor limestone, Devonian, New York: Hartnagel, 432.
Timpas limestone, Upper Cretaceous, Colorado: Stose, 1056.
Tonoloway limestone, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Totatlanika schist, Silurian or Devonian?, Alaska: Capps, 170.
Tradewater formation, Pennsylvanian, Kentucky: Glenn, 373.
Travis Peak formation, Cretaceous, Texas: Paige, 817.
Trent formation, Eocene, North Carolina: Clark *et al.*, 193.
Trenton, Ordovician, Vermont: Perkins, 845.
Trenton beds, Ordovician, New York: Hartnagel, 432.
Trenton formation, Ordovician, Ontario: Raymond, 888.
Trenton group, Ordovician, Quebec: Valiquette, 1132.
Trenton limestone, Ordovician, Pennsylvania: Ziegler, 1262.
"Trenton-Galena" limestone, Ordovician, Illinois: Lines, 670.
Trent River shales, British Columbia: Clapp, 184.
Tres Hermanos sandstone member, Cretaceous, New Mexico: Lee, 648.
Tribes Hill limestone, Ordovician, New York: Hartnagel, 432.
Tribune formation, Mississippian, Illinois: Lines, 670.
Tribune formation, Mississippian, Missouri: Crane, 233.
Tribune limestone, Carboniferous, Illinois: Shaw, 970.
Trinity formation, Cretaceous, Texas: Paige, 817.
Tully limestone, Devonian, New York: Hartnagel, 432.
Turgeon formation, Silurian, New Brunswick: Young, 1258.
Tuscarora sandstone, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Tuxedni sandstone, Jurassic, Alaska: Martin and Katz, 721.
Tuxpam beds, Miocene, Mexico: Dumble, 294.
Twin Creek limestone, Jurassic, Idaho and Utah: Richards and Mansfield, 903.
Tyner formation, Ordovician, Oklahoma: Snider, 1005.
Uinta epoch, Quaternary, Colorado: Atwood and Mather, 32.
Uinta formation, Eocene, Wyoming: Osborn, 815.
Uinta (?) formation, Tertiary, Utah: Lupton, 689, 690.
Uinta formation, Tertiary, Utah: Riggs, 917.
Uinta glacial epoch, Quaternary, Colorado: Atwood and Mather, 32.
Ulsterian group, Devonian, New York: Hartnagel, 432.
Unadilla terrane, Devonian, New York: Hartnagel, 432.
Uncas shale, Permian, Oklahoma: Ohern and Garrett, 803.
Uncompahgre interglacial interval, Quaternary, Colorado: Atwood and Mather, 32.
Union formation, Pliocene, Kentucky: Glenn, 373.
Union Hill diabase, Jura-Trias, New York: Hartnagel, 432.
Uniontown limestone, Carboniferous, West Virginia: Hennen, 447.
Uniontown limestone member, Pennsylvanian, Pennsylvania: Munn, 782.
Uniontown sandstone, Carboniferous, West Virginia: Hennen, 447.
Uniontown sandstone member, Pennsylvanian, Pennsylvania: Munn, 782.
Ute limestone, Cambrian, Idaho and Utah: Richards and Mansfield, 903.
Utica, Ordovician, Vermont: Perkins, 845.
Utica formation, Ordovician, Ontario: Raymond, 888.

Utica shale, Ordovician, New York: Hartnagel, 432.
Utica shale, Ordovician, Ohio: Fuller and Clapp, 346.
Utica shale, Ordovician, Pennsylvania: Ziegler, 1262.
Utica shale, Ordovician, Quebec: Valiquette, 1132.
Valcour limestone, Ordovician, New York: Hartnagel, 432.
Vancouver group, Jurassic and Triassic, British Columbia: Clapp, 183.
Vancouver group, Mesozoic, British Columbia: Clapp and Allan, 185.
Vancouver group, Triassic and Jurassic, British Columbia (Vancouver Island): Clapp, 182.
Vancouver volcanics, Jurassic, British Columbia (Vancouver Island): Clapp, 182.
Vancouver volcanics, Jurassic and other?, British Columbia: Clapp and Allan, 185.
Vanport limestone member, Pennsylvanian, West Virginia, Kentucky: Phalen, 850.
Vaqueros division, Miocene, California: Dumble, 293.
Vera Cruz graphite schist, Algonkian, Pennsylvania: Miller, 757.
Vergennes sandstone member, Pennsylvanian, Illinois: Shaw and Savage, 972.
Vernon shale, Silurian, New York: Hartnagel, 432.
Vinton member, Mississippian, Ohio: Hyde, 528.
Virginia slate, pre-Cambrian, Minnesota: Van Barneveld, 1133.
Wabash beds, Quaternary, Indiana: Hay, 437.
Wabaunsee formation, Pennsylvanian, Missouri: Hinds, 470.
Waccamaw formation, Pliocene, North Carolina: Clark, *et al.*, 193.
Wahkiakum formation, Miocene, Washington: Weaver, 1169.
Waits River limestone, Ordovician, Vermont: Richardson, 904; Richardson and Collister, 905; Richardson and Conway, 906.
Walden sandstone, Pennsylvanian, Georgia: Maynard, 738.
Wallace formation, pre-Cambrian, Idaho: Hershey, 452.
Wall Creek sandstone, Cretaceous, Wyoming: Jamison, 540.
Wall Creek sandstone lentil, Cretaceous, Wyoming, Wegemann, 1178.
Walnut clay, Cretaceous, Texas: Paige, 817.
Wamsutta red beds, Rhode Island: Barrell, 48.
Wapsipinicon limestone, Devonian, Iowa: Norton *et al.*, 800.
Wardner limestone, Mississippian, British Columbia: Schofield, 953.
Wark diorite, British Columbia (Vancouver Island): Clapp, 182.
Wark gneiss, Jurassic and Cretaceous?, British Columbia: Clapp and Allan, 185.
Warsaw formation, Mississippian, Illinois: Lines, 670.
Warsaw formation, Mississippian, Missouri: Crane, 233.
Warsaw terrane, Carboniferous, Iowa: Keyes, 577.
Wasatch formation, Eocene, Colorado: Lee, 647.
Wasatch formation, Tertiary, Colorado: Lee, 648.
Wasatch formation, Tertiary, Wyoming: Jamison, 539.
Wasatch formation, Tertiary, Utah: Lupton, 689, 690.
Wasatch series, Eocene, Wyoming: Osborn, 815.
Washakie formation, Eocene, Wyoming: Osborn, 815.
Washburn beds, pre-Cambrian, Wisconsin: Thwaites, 1085.
Washington fire clay shale, Carboniferous, West Virginia: Hennen, 447.
Washington formation, Permian, Pennsylvania: Munn, 782.
Washington limestone (upper), Carboniferous, West Virginia: Hennen, 447.
Washington (lower) limestone member, Permian, Pennsylvania: Munn, 782.
Washington (middle) limestone member, Permian, Pennsylvania: Munn, 782.
Washington (upper) limestone member, Permian, Pennsylvania: Munn, 782.
Watertown limestone, Ordovician, New York: Hartnagel, 432.
Waucoban or Lower Cambrian: Walcott, 1149.
Waynesburg limestone member, Pennsylvanian, Pennsylvania: Munn, 782.
Waynesburg sandstone, Carboniferous, West Virginia: Hennen, 447.
Waynesburg sandstone member, Permian, Pennsylvania: Munn, 782.
Weber grits, Carboniferous, Colorado: Patton *et al.*, 834.
Weber quartzite, Carboniferous, Utah: Boutwell, 92.
Weber shales, Carboniferous, Colorado: Patton *et al.*, 834.
Wedington sandstone member, Mississippian, Oklahoma: Snider, 1005.
Weisner quartzite, Cambrian, Georgia: Maynard, 738.
Wekwemikongsing beds, Ordovician, Ontario: Foerste, 329.
Wells formation, Pennsylvanian, Idaho and Utah: Richards and Mansfield, 903.
Wellsburg sandstone, Devonian, New York: Hartnagel, 432.
West Hill flags and shale, Devonian, New York: Hartnagel, 432.

GEOLOGIC FORMATIONS DESCRIBED—Continued.

West Index andesitic series, Tertiary?, Washington: Weaver, 1168.
West River shale, Devonian, New York: Hartnagel, 432.
Wheaton River volcanics, Tertiary or Pleistocene, Yukon: Cairnes, 149.
Whirlpool, Silurian, New York: Hartnagel, 432.
White Pine formation, Nevada: Hershey, 452.
White River formation, Oligocene, Wyoming: Winchester, 1231.
White River formation, Tertiary, South Dakota: Perisho and Visher, 843.
White River formation, Tertiary, Wyoming: Jamison, 539.
White River group, Oligocene, South Dakota: Osborn, 815.
Whiterock quartzite, Cambrian or pre-Cambrian, Nova Scotia: Faribault, 318.
Wichita formation, Texas: Udden, 1119; Udden and Phillips, 1121.
Wicomico formation, Pleistocene, Maryland: Miller, 758.
Wicomico formation, Pleistocene, Virginia: Clark and Miller, 192.
Wicomico formation, Pleistocene, North Carolina: Clark *et al.*, 193.
Wilberns formation, Cambrian, Texas: Paige, 817.
Wilbur limestone, Silurian, New York: Hartnagel, 432.
Williamson shale, Silurian, New York: Hartnagel, 432.
Wills Creek shale, Silurian, West Virginia, Pennsylvania, Maryland: Stose and Swartz, 1058.
Wilson formation, Carboniferous, Oklahoma: Ohern and Garrett, 803.
Wind River formation, Tertiary, Wyoming: Woodruff and Winchester, 1246.
Wind River series, Eocene, Wyoming: Osborn, 815.
Windsor series, Mississippian, New Brunswick: Bell, 65.
Windy Gap limestone, Carboniferous, West Virginia: Hennen, 447.
Winfield limestone, Permian, Oklahoma: Ohern and Garrett, 803.
Winnipeg limestone, Ordovician, Ontario: Lawson, 637.
Wisconsin drift, Quaternary, Illinois: Udden, 1117.
Wisconsin stage, Quaternary, Indiana: Shannon, 966.
Wisconsin terrane, Quaternary, Iowa: Keyes, 577.
Wiscoy shale and sands, Devonian, New York: Hartnagel, 432.
Wolcott limestone, Silurian, New York: Hartnagel, 432.
Wolf Creek conglomerate, Mississippian, New York: Hartnagel, 432.
Woodbury terrane, Cretaceous, Iowa: Keyes, 577.
Woodside shale, Triassic, Idaho and Utah: Richards and Mansfield, 903.
Woodside shale, Triassic, Utah: Boutwell, 92.
Woodstock greensand marl member, Eocene, Virginia: Clark and Miller, 192.
Woodstock marl member, Eocene, Maryland: Miller, 758.
Worcester phyllite, Carboniferous, Massachusetts: White, 1194.
Worcester quartzite, Carboniferous, Massachusetts: White, 1194.
Wreford limestone, Permian, Oklahoma: Ohern and Garrett, 803.
Yarmouth terrane, Quaternary, Iowa: Keyes, 577.
Yonkers gneiss, pre-Cambrian, New York: Hartnagel, 432.
Yorktown formation, Miocene, North Carolina: Clark *et al.*, 193.
Yorktown formation, Miocene, Virginia: Clark and Miller, 192.
Yule limestone, Ordovician, Colorado: Patton *et al.*, 834.

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 546

MINERAL RESOURCES OF SOUTH-WESTERN OREGON

BY

J. S. DILLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

CONTENTS.

	Page.
Introduction	9
Purpose and scope of the bulletin	9
Field work	9
Acknowledgments	9
Geography of the region	11
General relations of the Klamath Mountains	11
Topography and physiography of southwest Oregon	12
Geology	14
Sedimentary rocks	14
Mica schist	14
Paleozoic rocks	14
Lithologic character	14
Distribution of limestone	15
Age of the Paleozoic limestones	15
Composition of the limestones	16
Relation of the Paleozoic to adjacent rocks	17
Jurassic system	17
Lithologic character	17
Formations and age	17
Relations of Jurassic formations	18
Cretaceous system	18
Tertiary system	19
Igneous rocks	19
Structure	21
Mineral production of southwestern Oregon	22
Lode mines and prospects	23
Gold-quartz lode mines	23
General features	23
Blue River mining region	25
Bohemia mining region	26
Port Orford quadrangle	30
Roseburg quadrangle	31
Riddles quadrangle	31
Mining conditions	31
Greenback mine	31
Martha mine	34
Baby mine	34
Silent Friend mine	35
Daisy mine	35
Mount Pitt mine	36
Orofino mine	36
Other mines in the greenstone areas	37
Corporal G mine	37
Lucky Bart group	38
Conclusions	39

Lode mines and prospects—Continued.
Gold-quartz lode mines—Continued. Page.
Grants Pass quadrangle and Medford district........................ 39
Braden mine........................ 39
Opp mine........................ 41
Granite Hill mine........................ 42
Mountain Lion mine........................ 43
Tin Pan mine........................ 43
Star mine........................ 44
Maid of the Mist mine........................ 44
Jewett mine........................ 44
Oregon Strong Ledge........................ 45
Other mines and prospects........................ 45
Galice-Kerby-Waldo region........................ 46
General features........................ 46
Oriole mine........................ 48
Richmond group........................ 50
Golden Wedge mine........................ 51
Arago group........................ 51
Seven-Thirty mine........................ 51
Kramer prospect........................ 52
Elwilda (Hubbert) mine........................ 52
Gold Bug and mines of Mount Reuben........................ 52
Mount Bolivar region........................ 53
Keystone group........................ 53
Legal Tender group........................ 54
Treasury group........................ 54
Red Elephant claims........................ 54
Blue Bell prospect........................ 55
Buffalo group........................ 55
Mayflower property........................ 56
Black Bear mine........................ 56
Spokane property........................ 57
Black Hawk property........................ 57
Nesbit group........................ 57
Three Lodes group........................ 57
Golden Pheasant group........................ 58
Sugar Pine mine........................ 58
Gold Plate property........................ 59
Victor mine........................ 59
Strenuous Teddy claim........................ 59
Cold Spring copper mine........................ 60
Carlton group........................ 60
Lost Flat mine........................ 60
Queen Gold & Copper mine........................ 60
Buckeye mine........................ 61
Ramsey mine........................ 61
Old Glory property........................ 62
Eureka mine........................ 62
G E. Anderson prospect........................ 63
Calumet mine........................ 63
Casey prospect........................ 64
Higgins mine........................ 64
Black Bear claim........................ 65

Lode mines and prospects—Continued.
Gold-quartz lode mines—Continued.
Galice-Kerby-Waldo region—Continued. Page.
Hustis and Anderson claims 65
Miller and Bacon prospects 65
Williams & Adylott mine 66
Gold Ridge prospects 66
Philips property 67
Chatty mine 67
Mood mine 68
Neil mine 68
Canyon Creek Consolidated Gold mines 68
Bowden prospects 69
Winters and McPherson prospects 69
Alta mine 70
Roseburg and Fidelity groups 70
Free and Easy mine 71
Other mines 71
Copper mines and prospects 71
Copper production 71
Copper deposits 72
Distribution 72
General character 72
Almeda mine 72
General features 72
Character of the ore 75
Origin of the ore 79
The smelter 80
Queen of Bronze mine 81
Other copper prospects in the Waldo region 83
Reynolds mine 84
Chetco Copper Co. mine 84
United Copper-Gold Mines Co. mine 84
Calumet mine 85
Collier Creek prospect 85
Thompson mine 86
Green Mountain Copper prospect 86
Copper prospects of the Riddles quadrangle 87
Placer mines 88
Auriferous gravels (conglomerates) of Cretaceous age 88
General character 88
Cottonwood district, California 89
The Forty-Nine mines of the Ashland region, Oregon, by Frank M. Anderson 90
Historical sketch 90
Geology of the district 91
The "Bedrock series" 91
Cretaceous conglomerate of Waldo 93
General character 93
High Gravel (Osgood) mine 94
Auriferous gravels of the first cycle of erosion (Klamath peneplain) 95
Age of the Klamath peneplain 95
Situation of the gravel beds 95
Gravels of Gold Basin 96
Gravel near York Butte 96

Placer mines—Continued.	Page.
Auriferous gravels of the second cycle of erosion	97
Location and character	97
Old-channel gravel near Galice Creek	98
Old-channel gravels near Briggs Creek	101
Auriferous gravels of the third cycle of erosion	102
General features	102
Placers of Sixes River and Johnson Creek	102
Placers of the Umpqua and its tributaries	103
Placers of Rogue River and its tributaries	104
Wolf Creek district	104
Grave Creek district	104
Jumpoff Joe district	105
Evans Creek district	106
Gold Hill district	106
Foots Creek district	107
Champlin mine	107
Black Gold Channel mine	108
Cook mine	109
Lance mine	109
Glen Ditch and other mines	109
Jacksonville district	109
Sterling mine	109
Spaulding mine	110
Old Sturgis mine	110
Pearce mine	111
Pickett Creek district	111
Big Four mine	111
Flanagan & Emerson mine	112
Galice district	112
Lower Rogue River district	114
General features	114
Tyee Bar mine	114
Horseshoe Bar mine	114
Battle Bar mine	115
Winkle Bar mine	115
Red River Gold Mining & Milling Co. mine	115
Applegate district	116
Layton mine	116
Johnston mine	116
Benson mine	117
Brantner mine	117
Williams Creek district	117
Horsehead mine	117
Miller & Savage mine	118
Oscar Creek mine	118
Althouse and Sucker Creeks district	118
Waldo district	118
Development	118
Deep Gravel mine	119
Logan, Simmons & Cameron mine	120
Josephine Creek district	120
Illinois River district	122
Anderson & Wilson mine	122
Sixmile Creek mine	123
Briggs Creek district	124

Placer mines—Continued.
Auriferous gravels of the third cycle of erosion—Continued. Page.
Placers on residual deposits.......... 124
Beach placers.......... 125
Development of mining.......... 125
Bandon district.......... 125
Cape Blanco district.......... 126
Eckis mine.......... 127
Platinum.......... 128
Quicksilver.......... 129
Nickel.......... 129
Coal.......... 130
Production and character.......... 130
Coos Bay coal field.......... 130
General features.......... 130
Geology.......... 133
Stratigraphy.......... 133
Structure.......... 133
Northern part of the field.......... 134
Middle part of the field.......... 135
Southern part of the field.......... 135
Eckley coal field.......... 136
Eden coal field.......... 136
Lookingglass and Camas Valley fields.......... 139
Coal field on the North Fork of the Umpqua.......... 139
Rogue River valley coal field.......... 140
Geological Survey publications on southwestern Oregon.......... 141
Index.......... 143

ILLUSTRATIONS.

		Page.
PLATE I.	Even crest of Coast Range as seen from Barklow Mountain, Curry County, Oreg	12
II.	Even crest of Iron Mountain, Curry County, Oreg	13
III.	*A*, Even crest of Klamath Mountains southwest of Waldo, Oreg.; *B*, Klamath peneplain	14
IV.	Map showing limestone outcrops in Grants Pass quadrangle and bordering districts	16
V.	Map showing the most important gold-quartz mines of the Grants Pass quadrangle	40
VI.	Geologic reconnaissance map of the Galice-Kerby-Waldo region	46
VII.	Cretaceous conglomerate in Forty-nine mine, near Phoenix, Oreg	92
VIII.	Map showing distribution of Tertiary and later auriferous gravels in southwestern Oregon	96
IX.	Map of north part of Coos Bay coal field	134
X.	Map of middle part of Coos Bay coal field	134
XI.	Map of T. 27 S., R. 13 W., Coos Bay coal field	134
FIGURE 1.	Index map showing topographic sheets and geologic folios published for southwestern Oregon	10
2.	Geologic map of the Klamath Mountains and adjacent ranges	11
3.	Generalized cross section of a river valley	13
4.	Generalized section across Jurassic belt northwest of Grants Pass	18
5.	Map of the Bohemia region, showing its accessibility by the Southern Pacific Railroad	26
6.	Map of part of the Riddles quadrangle, showing the most important gold-quartz mines in 1907	32
7.	Section of contact in Oriole mine	49
8.	Plan and longitudinal section of Almeda mine	73
9.	An approximate shore line of Cretaceous islands when auriferous gravel beaches were formed	89
10.	Geologic section across Cottonwood Valley, Cal	90
11.	Section of tailrace of Logan mine	94
12.	Cross section of Logan mine, 3½ miles north of Waldo	94
13.	Section showing relations of gravel of York Butte	97
14.	Section of Old Channel mine at Home Place	98
15.	Section of gravel in Old Channel mine at Home Place	99
16.	Section on western edge of Old Channel mine, north side of Rich Gulch	99
17.	Section of gravel in Old Channel mine, north of Rich Gulch	100
18.	Section of gravel in Old Channel mine, south of Rich Gulch	100
19.	Profile of old-channel bedrock in Harvey mine	101
20.	Section of old-channel deposit at Column Rock	101
21.	Cross-section profile of Josephine Creek	121
22.	Coal fields of southwest Oregon	131
23.	Map of Coos Bay coal field	132
24.	Map showing location of Eden coal field	136
25.	Map of Eden coal field	137
26.	Generalized section of Eden coal field	138

MINERAL RESOURCES OF SOUTHWESTERN OREGON.

By J. S. DILLER.

INTRODUCTION.

PURPOSE AND SCOPE OF THE BULLETIN.

There are frequent calls at the United States Geological Survey for information concerning southwestern Oregon. The information desired has in part been published by the Geological Survey as separate reports, the supply of nearly all of which has been exhausted. Although a detailed survey of southwestern Oregon has not yet been completed, enough has been done to warrant a preliminary report of results attained with reference to the mineral resources, especially the metals.

FIELD WORK.

In the autumn of 1883, while making a general reconnaissance of the Cascade Range, I traversed southwestern Oregon, and at various times since then my reconnaissance has been extended and detailed surveys have been made of a number of quadrangles in that portion of the State. The index map (fig. 1) shows the areas of which detailed surveys have been completed and topographic maps and geologic folios published. This map also shows the location of Blue River and Bohemia districts, concerning which the Geological Survey has published reports, as well as the Galice-Kerby-Waldo region, a report on which, containing the results of a reconnaissance made in the summer of 1911, is given in this bulletin. At the end of the bulletin is a list of Geological Survey publications concerning southwestern Oregon.

ACKNOWLEDGMENTS.

In acknowledging the courteous aid rendered by the many mine owners and others with whom I came in touch during the progress of the work I can mention only a few of those whose services have been of special importance. I am greatly indebted to Will Q. Brown, geologist, of Riddles, Oreg., for much general and special aid extended through many years; also to P. H. Holdsworth, of the Almeda; Fayette A. Jones, of the Oriole; C. L. Barlow, of Galice; W. S. Bacon and P. F. Hogue, of Kerby; W. S. Bowden and C. L. Mangum, of Grants Pass; E. W. Liljegran, of Medford; and many other residents of southwestern Oregon.

Special mention is made of my indebtedness to members of the Forest Service, particularly to H. V. Anderson, of Kerby, and to those in charge of the Portland office for maps of the Siskiyou National Forest, which were used not only in the field, but also as a base for the geologic map of the Galice-Kerby-Waldo region (Pl. VI).

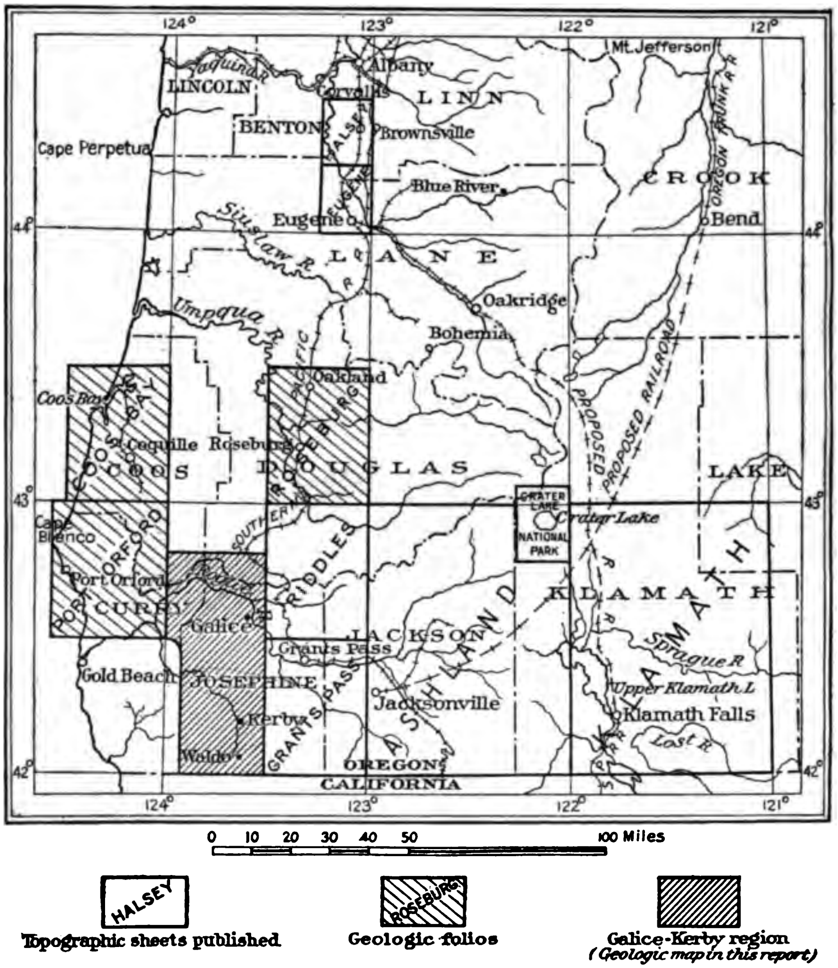


FIGURE 1.—Index map showing topographic sheets and geologic folios published for southwestern Oregon.

Special mention should be made also of Frank M. Anderson, who contributed the account of the Forty-nine mines. (See pp. 90–93.)

My greatest indebtedness is to Prof. G. F. Kay, now State geologist of Iowa, who a few years ago examined the mines of the Riddles and Grants Pass quadrangles and from whose publications [1] I have made numerous extracts for this report.

[1] Diller, J. S., and Kay, G. F., The mines of the Riddles quadrangle, Oregon: U. S. Geol. Survey Bull. 340, p. 134, 1908; Mineral resources of the Grants Pass quadrangle and bordering districts, Oregon: U. S. Geol. Survey Bull. 380, p. 48, 1909.

GEOGRAPHY OF THE REGION.

GENERAL RELATIONS OF THE KLAMATH MOUNTAINS.

To describe the general relations of the southwestern portion of Oregon it is necessary to consider briefly the geography and geology

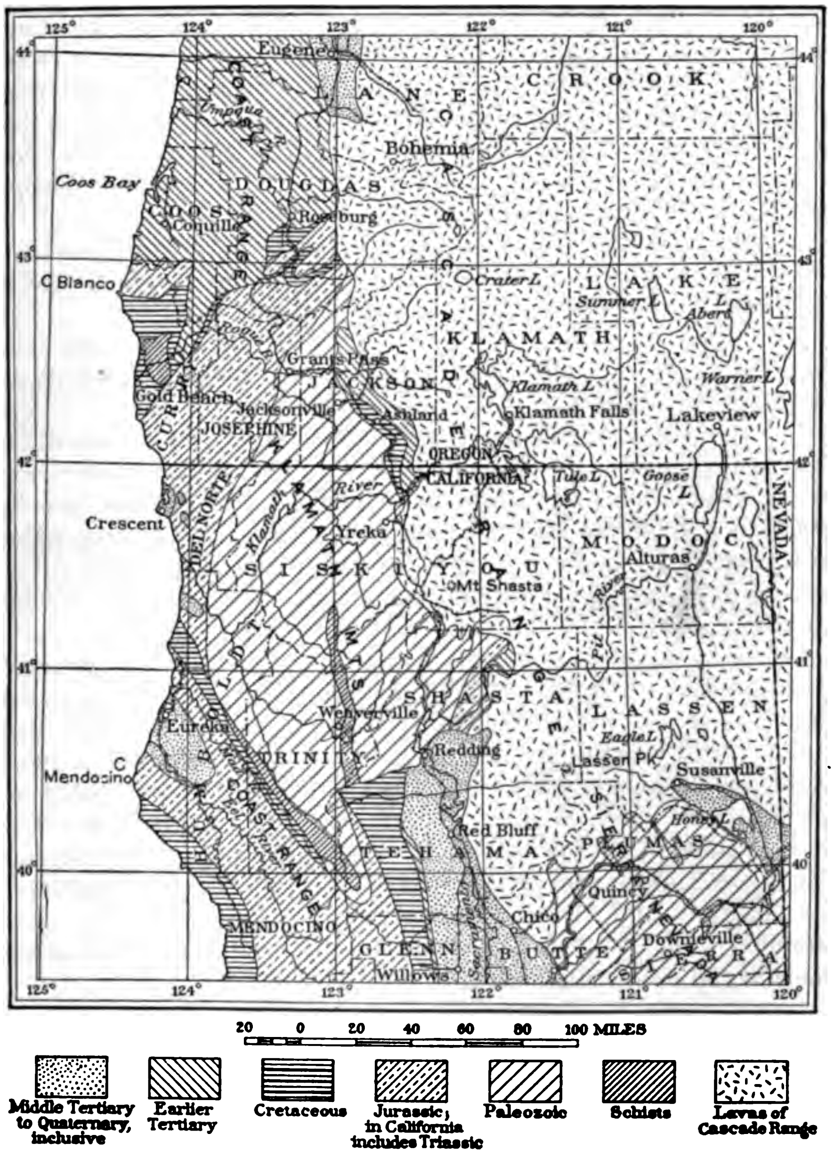


FIGURE 2.—Geologic map of the Klamath Mountains and adjacent ranges.

of the adjacent mountain ranges. The mountain belt of the Pacific coast in California and Oregon includes a number of distinct ranges,

whose distribution and relations are in part illustrated by the accompanying map (fig. 2).

On the north are the Cascade Range and the Coast Range of Oregon, separated by the Willamette or Sound Valley as far south as Eugene. On the south are the Sierra Nevada and the Coast Range of California, separated by the Great Valley of California. Surrounding the western part of the California-Oregon boundary, where all these ranges appear to meet, there is a distinct group of mountain ridges and peaks, extending from a point beyond the mouth of Rogue River in Oregon to Mad River and the Sacramento Valley in California, that constitutes the Klamath Mountains. They embrace the South Fork, Trinity, and Salmon Mountains of California, as well as the Siskiyou and Rogue River Mountains in Oregon. The greater portion of the mining region of southwest Oregon is in the Klamath Mountains about Grants Pass, although it reaches into the Cascade Range at Bohemia and the Coast Range beyond Port Orford.

The distinction of these ranges is based largely on geologic data, and will be more readily understood by referring to the geologic map (fig. 2).

The symbols on the map indicate in general the geologic age of the sedimentary rocks. To illustrate their areal distribution more clearly all details of small areas have been omitted and outlines broadly generalized to cover large areas of igneous rocks. The map shows at a glance that although practically all the formations outlined are present in southwest Oregon, the sedimentary rocks form but a small portion of the great insular mass of the Klamath Mountains.

Before the formations are considered separately it may be observed that the Klamath Mountains are composed in the main of essentially the same formations as the Sierra Nevada, and furthermore that although in the southern part of the Klamath Mountains the trend of the formations and lines of structure are northwest and southeast, toward the Sierra Nevada, in the northern portion the trend is southwest and northeast, toward the Blue Mountains of eastern Oregon. This general alignment of the formations of the Sierra Nevada and the Klamath and Blue mountains applies also to their mineral resources, in which they are strongly contrasted with those of the Cascade and Coast ranges of Oregon and California.

TOPOGRAPHY AND PHYSIOGRAPHY OF SOUTHWEST OREGON.

To obtain an impressive view of the general features in the relief of southwest Oregon one must climb from a narrow river gorge up the steep slopes of the canyon to gentler slopes, which rise in places to flat-topped summits on the main divides. Although great diversity exists in the scenic details of the mountains and valleys, there

EVEN CREST OF COAST RANGE AS SEEN FROM BARKLOW MOUNTAIN, CURRY COUNTY, OREG.

EVEN CREST OF IRON MOUNTAIN, CURRY COUNTY, OREG.

are but three general features, whose relations may be illustrated by figure 3.

The flat-topped summits (*a*) are remnants of a once continuous plain of gentle relief due to erosion and now generally known as the Klamath peneplain. The earlier valley (*b*) of the river is broad with gentle slopes and strongly contrasts with the later valley (*c*), the canyon in which the river now flows.

The Klamath peneplain forming the even crest of the Coast Range, as seen from Barklow Mountain, is illustrated in Plate I.

The comparatively even crest of Iron Mountain at an altitude of 4,000 feet in Curry County (Pl. II) shows the same feature, but the largest area of the Klamath peneplain in southwest Oregon is near the California line, west and southwest of Waldo (Pl. III, *A* and *B*), where it is traversed at an altitude of about 4,000 feet by the old wagon roads to the coast.

The Klamath peneplain is the result of the first cycle of erosion recorded in the topography of that region, and in Oregon only the highest peaks, like Preston and the summits of the Siskiyou, rise as prominent hills (monadnocks) above its general level.

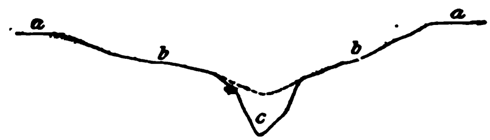


FIGURE 3.—Generalized cross section of a river valley, showing the relation of the Klamath peneplain (*a*) to the earlier valley (*b*) and the later valley (*c*).

The Klamath peneplain has been differentially uplifted from an altitude near the sea level and deformed, so that portions of it may now appear at different levels. In general the plain rises toward the Siskiyou and Salmon Mountains, where the uplift has been greatest.

The rivers rejuvenated by the uplift deepened and widened their valleys to gentle slopes during the second cycle of erosion, forming for each river what is indicated in the diagram as an earlier valley.

Subsequent uplift rejuvenated the streams and initiated a third cycle of erosion, during which the streams cut deep, narrow, commonly canyon-like valleys in the bottoms of the earlier valleys. In the soft rocks the later valleys have been widened generally, and in many places gravel terraces form benches on their slopes.

The uplifts which resulted in carving earlier and later valleys out of the Klamath peneplain were irregular and intermittent, and a record was made of them along the coast in the elevated beaches carved by the waves on successive shore lines at the halting points of the rising land. The longer the halt the larger the coastal plain developed. About the time the earlier valleys were completed a peneplain of considerable size, much lower than the Klamath peneplain, was developed at favorable points along the coast.

One of the most important conditions contributory to the formation of rich auriferous gravels is the deep weathering and disintegration of rocks that contain gold-bearing quartz veins. By this means the gold is liberated in the residual material and prepared for concentration by the streams in their gravel beds. That auriferous gravels commonly originate in connection with peneplains is evident in the Sierra Nevada, where the high gravels are associated with the low relief of the peneplain and contain a large amount of residual material resulting from deep rock weathering on gentle slopes.

In the Klamath Mountains, as in the Sierra Nevada, it is evident that in the development of the Klamath peneplain much gold must have been liberated for concentration in stream beds belonging to the first, second, and third cycles of erosion.

GEOLOGY.

SEDIMENTARY ROCKS.

MICA SCHIST.

Near the mouth of Rogue River is an area of schistose rocks, in part mica schist intermingled with slates in which the cleavage is highly developed. These rocks are invariably fine grained, rich in quartz, and where most highly metamorphosed have much fine silky mica (sericite) on the foliated surface. They are much folded and crumpled, and on Brushy Bald Mountain pass into less-altered fragmental rocks.

A small area of these schistose rocks, not marked on the map, occurs 8 miles northeast of Crescent City. It is probably related to the long area in South Fork Mountain, where the more typical mica schists are developed.

Another belt of these rocks, the Abrams formation of Hershey,[1] extends north from the vicinity of Weaverville into the heart of the Klamath Mountains and is possibly related to a mass of well-developed mica schist on the Oregon line at the head of Applegate Creek, about 30 miles southwest of Ashland.

The age of these schists is not definitely known. Though some of them appear to be older than the associated Devonian rocks, others have resulted from the alteration of adjacent Carboniferous or later rocks by the intrusion of the neighboring granodiorite.

PALEOZOIC ROCKS.

Lithologic character.—The Paleozoic sediments consist of clay shales or slates, gray to dark siliceous, locally banded slates, and greenish slates, interbedded with volcanic tuffs and lentils of limestone, some thin-bedded sandstone, and some fine conglomerate.

[1] Am. Geologist, vol. 27, p. 226, April, 1901.

A. EVEN CREST OF KLAMATH MOUNTAINS SOUTHWEST OF WALDO, OREG.

B. KLAMATH PENEPLAIN.

Looking northwest from the vicinity of the point from which the view shown in *A* was taken.

Many of the siliceous beds are flinty and contain the remains of microscopic radiolarians, thus proving the oceanic origin of the material.

With these sediments is associated a very much larger proportion of igneous rocks, partly volcanic rocks of Paleozoic age and partly intrusive rocks of later date. The igneous rocks will be noted more particularly under a separate heading, not only on account of their large volume but because of their genetic relation to the metalliferous deposits.

In southwest Oregon by far the greater portion of the area marked Paleozoic is of igneous rocks, and this proportion continues well down into the central portion of the Klamath Mountains, but in the southern part of the Klamath Mountains and the Sierra Nevada the proportion of sedimentary rocks increases.

Distribution of limestone.—Limestone is one of the most important Paleozoic and Mesozoic sedimentary rocks in southwest Oregon and is especially valuable on account of its relation to the cement industry. The Paleozoic limestones only will be noticed at this place, those of Mesozoic age being described under the Cretaceous system. More limestone occurs in the Grants Pass quadrangle than in any other quadrangle of equal size in southwest Oregon.

The area occupied mainly by the Paleozoic rocks, both sedimentary and igneous, in the Applegate region has a width directly across the strike of about 30 miles, in which there are four more or less clearly defined belts of limestones containing about 50 masses, most of which are shown on the map (Pl. IV). The largest outcrop is not over one-third of a mile in length and 200 feet in thickness.

The first belt of limestone includes prominent ledges 3 miles southeast of Kerby as well as several on Cheney Creek, where the conditions are favorable for handling the material and for getting it to Grants Pass by an easy haul of 12 miles.

The second belt is less regular. It extends from the vicinity of Gold Hill, on the main line of the Southern Pacific Co., southwestward by the Oregon Bonanza mine to the well-known Oregon Caves, and beyond into California.

The third belt, which has several readily accessible ledges on Kane Creek, appears to the southwest on Applegate River, on Steamboat Creek, and in the vicinity of Whisky Peak, where the belt enters California.

The fourth belt of limestone appears on Little Applegate River, and possibly also on Applegate River near Watkins, where a prominent limestone lens occurs close to the mica schist, which it appears to overlie.

Age of the Paleozoic limestones.—The limestones at a number of points in Josephine and Jackson counties are fossiliferous, but the

fossils are too poorly preserved to permit definite determination. However, they are sufficient to suggest that the first and second belts noted above are of Devonian age, whereas the third and fourth are Carboniferous. These intermittent belts of limestone lenses have been traced far southward into California throughout the Klamath Mountains, where additional belts of highly fossiliferous limestone appear and leave no doubt concerning their Devonian and Carboniferous age.

Composition of the limestones.—For the purpose of showing the adaptability of these limestones to the manufacture of cement the following analyses were made by R. C. Wells in the chemical laboratory of the United States Geological Survey at Washington:

Analyses of limestone from Grants Pass quadrangle, Oreg.

	1	2	3	4	5	6	7
Calcium oxide (CaO)	55.28	55.71	55.34	41.83	55.55	55.06	55.38
Carbon dioxide (CO_2)	43.57	43.54	43.23	32.57	43.63	43.25	43.51
Water (H_2O)	.50	.37	.56	.46	.26	.50	.40
Silica (SiO_2)	.23	.37	.31	23.86	.13	.53	.06
Alumina and iron oxide ([Al, Fe]$_2O_3$)	.28	.20	.44	.32	.38	.52	.62
Magnesia (MgO)	.03	.01	.03	Trace.	None.	Trace.	Trace.
	99.89	100.20	99.04	99.04	99.95	99.85	99.97

1. Specimen 7015 A, sec. 19, T. 37 S., R. 6 W.
2. Specimen 7017 A, Carter's quarry, sec. 2, T. 37 S., R. 3 W.
3. Specimen 7017 B, Householders' quarry, sec. 2, T. 37 S., R. 3 W.
4. Specimen 7021, ridge 1 mile southwest of Gold Hill, sec. 20, T. 36 S., R. 3 W.
5. Specimen 7025, marble southwest of Williams, sec. 31, T. 38 S., R. 5 W.
6. Specimen 7045, Applegate River, south of Watkins, in sec. 7, T. 41 S., R. 4 W.
7. Specimen 7074, 3 miles S. 70° E. of Kerby.

An analysis of the limestone from the vicinity of Rock Point, 3 miles west of Gold Hill, made by J. S. Phillips, is as follows:[1]

Analysis of limestone from vicinity of Rock Point, Oreg.

Silica	3.1
Iron oxide	2.2
Lime carbonate	89.4
Magnesium carbonate	5.3
	100.0

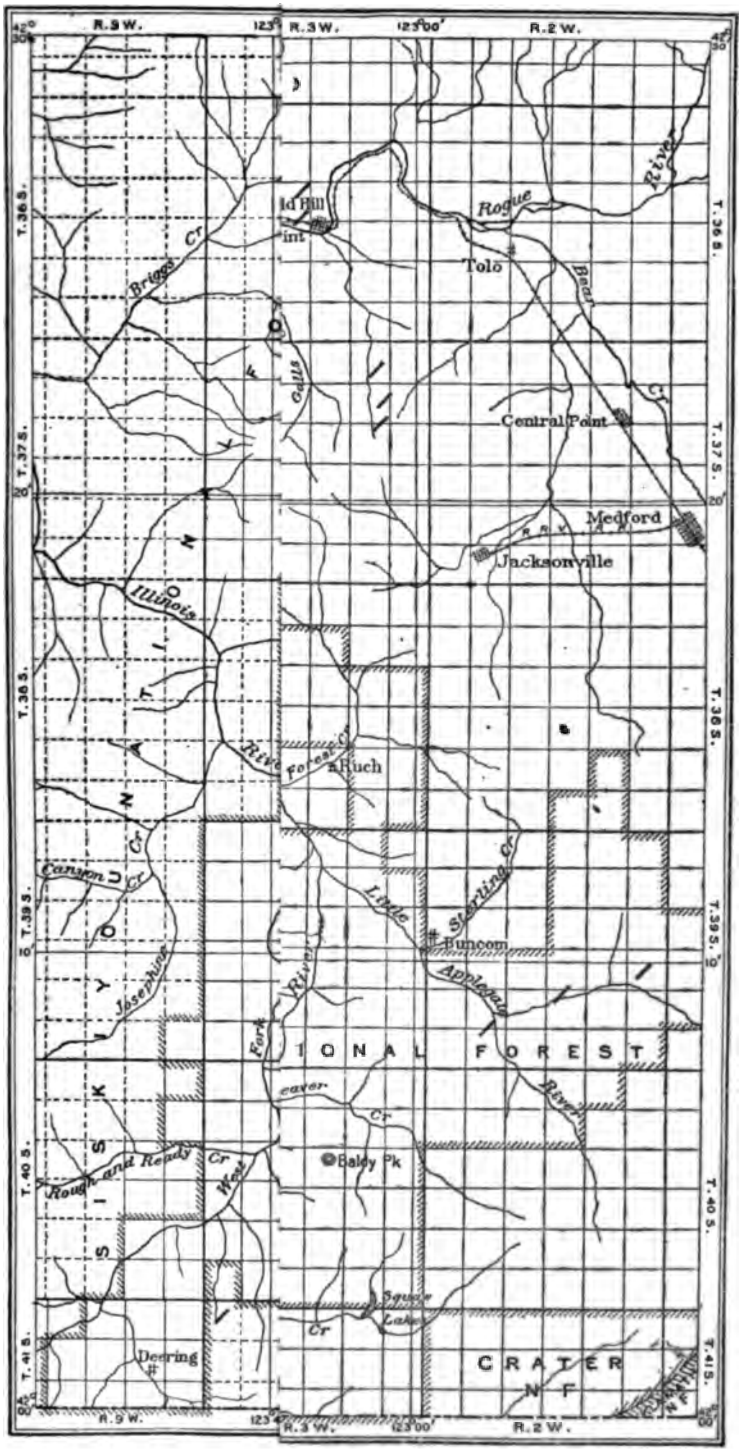
Two analyses by P. H. Bates of limestone obtained near Gold Hill are as follows:[1]

Analyses of limestone from vicinity of Gold Hill, Oreg.

	1	2
Silica	0.92	25.21
Lime carbonate	98.22	69.82
Magnesium carbonate	.84	1.30
	99.98	96.33

1. One mile northwest of Gold Hill. 2. One-fourth mile west of Gold Hill.

[1] Darton, N. H., Structural materials in parts of Oregon and Washington: U. S. Geol. Survey Bull. 387, p. 29, 1909.


R. 9 W.
R. 3 W.
R. 2 W.
123° 00'
T. 36 S.
T. 37 S.
T. 38 S.
T. 39 S.
T. 40 S.
T. 41 S.
Rogue River
Tolo
Bear Cr
Briggs Cr
Central Point
Medford
Jacksonville
Illinois River
Ruch
Forest Cr
Little
Sterling Cr
Buncom
Applegate River
Canyon Cr
Josephine Cr
Fork River
ONAL FOREST
Cr
Baldy Pk
Rough and Ready Cr
West
Squaw Lake
Deering
CRATER N F
SISKIYOU NATIONAL FOREST

RICTS.

Lime has been burned from several of the limestones noted above, and some has been used for flux. With the coal and the shales or clay of Rogue River valley it seems probable that some of the limestone of that region could be used to advantage in the manufacture of cement.

Relation of the Paleozoic to adjacent rocks.—The strata included in the four belts of limestone and associated rocks of Paleozoic age in southwest Oregon, if judged by their attitude and distribution, appear to be conformable throughout, although they are apparently unconformable not only to the older mica schists, but also to the younger Jurassic rocks.

JURASSIC SYSTEM.

Lithologic character.—The Jurassic sedimentary rocks of southwest Oregon consist mainly of shales or slates and thin-bedded sandstones in variable proportions. Small beds of fine siliceous conglomerate are rare. The shales are dark, locally black, but weather gray, yellowish, or brown, and here and there are decidedly slaty. The sandstones are gray and hard. Locally in the sandstones quartz veins are decidedly abundant, but generally they are scarce or absent. The fine conglomerate of quartzose pebbles contains scattered on its surface small cavities from which soluble pebbles have disappeared. Variously colored chert, generally gray or red, is common in some localities. Near the contact with granite or other intrusives these rocks are in places altered to mica schist or blue hornblende schist. Jurassic sediments occupy only about half of the broad belt indicated in southwest Oregon west of Grants Pass, the other portion being occupied by igneous rocks, partly volcanic but mainly intrusive and of wide range in general character and composition.

Formations and age.—The belt referred to above is shown in greater detail on the map of the Galice-Kerby-Waldo region (Pl. VI, p. 46), where the Jurassic sedimentary rocks are represented as two formations—the Galice formation on the southeast and the Dothan formation on the northwest—separated by an irregular belt of igneous rocks, mainly varieties of greenstone and serpentine. Characteristic late Jurassic fossils have been found in the slates of the Galice formation at the Almeda mine and also on Cow Creek, at the mouth of Rattlesnake, near Reuben Spur, showing that they are of about the same horizon as the Mariposa slate of the Mother Lode region in California.

The Dothan formation is composed mainly of slates and thin-bedded hard sandstones, with some conglomerate and cherts. Fossils are rare and as far as known are so similar to those of the slates of the Galice formation as not to be distinctive.

Relations of Jurassic formations.—The relative position of the two formations is shown in the generalized section of the Jurassic belt northwest of Grants Pass (fig. 4). The section represented is about 40 miles in length. The Devonian strata of the Kerby region on the southeast are carried up by a thrust fault so as to rest on the overturned slates of the Galice formation. The general dip of the strata is to the southeast, but the newer strata are on the northwest, where the Knoxville is unconformably overlain by the Eocene. The Dothan and Galice appear to be overturned, and their relative position indicates that the Dothan is younger than the Galice.

The great mountain-building epoch at the close of the Jurassic involved the irruption of great masses of igneous rocks and finally resulted in the formation of important metalliferous deposits. Nearly all such deposits in Jurassic rocks occur in those of igneous origin.

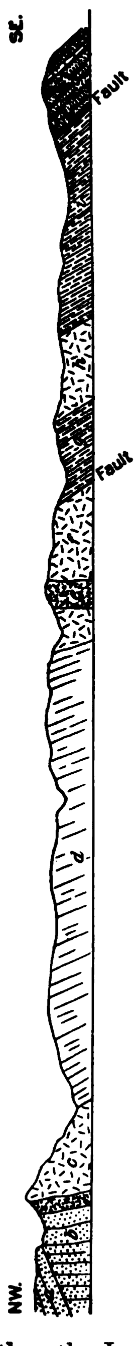


FIGURE 4.—Generalized section across Jurassic belt northwest of Grants Pass. *a*, Eocene; *b*, Cretaceous; *c*, greenstone; *d*, Dothan formation; *e*, serpentine; *f*, greenstone; *g*, Galice formation; *h*, greenstone; *i*, Galice formation; *j*, Paleozoic.

CRETACEOUS SYSTEM.

The Cretaceous rocks of southwest Oregon are comparatively soft conglomerates, sandstones, and shales, which on the basis of fossil evidence have been divided into the Knoxville, Horsetown, and Chico formations. A number of limestone ledges and some chert occur in the Knoxville north of Riddles. The Knoxville, Horsetown, and Chico formations once formed a continuous blanket for the older rocks over almost the whole of the Klamath Mountains, but most of this cover has been washed away, and the evidence of it is found only in the fossiliferous pebbles of the early auriferous gravels in that region. Remnants of this blanket occur along the western edge of Rogue River valley, also near Waldo in the Logan mine outlet, and on Grave Creek 6 miles east of Placer, as well as in the vicinity of Riddles and for miles along the coast. The Cretaceous is markedly unconformable to the Jurassic rocks beneath and is in general slightly unconformable to the overlying Eocene.

As the Cretaceous rocks are younger than the intense rock folding that closed the Jurassic, they are much less crushed, indurated, and veined with quartz than the Jurassic rocks. Locally, however, the Knoxville strata contain small quartz veins, but they do not contain any important lode mines.

TERTIARY SYSTEM.

The early Tertiary (Eocene) of western Oregon is largely developed in the Coast Range, extending as far south as the mouth of Illinois River. It is chiefly soft yellowish sandstone but contains much shale and some conglomerate. Beds of coal occur at a number of places, more particularly in the vicinity of Coos Bay. On the eastern side of Rogue River valley the sandstones and shales, with some coal, dip eastward beneath the lavas of the Cascade Range. Similar beds occur on the Great Bend of Pit River and along the western border of the Sacramento Valley.

The middle Tertiary and later formations, including the Quaternary, chiefly clays, sands, and gravels, more or less indurated, form scattered patches along the coast where they are marine, and fill the broad river valleys inland where they are fluviatile. For the sake of clearness they are shown on the map only in the Sacramento Valley, the Willamette Valley, and about Honey Lake, but in fact they occur as auriferous gravels, once extensively mined, along all the important streams throughout the Sierra Nevada and Klamath mountains.

IGNEOUS ROCKS.

In southwest Oregon igneous rocks are abundant and cover a greater area than the sedimentary rocks. They are of great variety in composition, texture, and mode of occurrence, including greenstones, serpentine, granodiorite, dacite porphyry, and augite andesite.

The greenstones are widespread and of several different kinds, both effusive and intrusive, but for the most part they agree in being much altered pyroxenic rocks, greenish in color from the presence of chlorite or green hornblende.

The effusive volcanic greenstones spread over the surface as andesitic lavas rich in pyroxene, possibly some of them basaltic. They are abundant among the Paleozoic limestones and other sediments, especially in the Gold Hill and Applegate region, where they are in some places vesicular and associated with fragmental deposits due to explosive volcanic action.

Similar volcanic greenstones occur among the Mesozoic strata, particularly in the neighborhood of Rogue River a short distance above Galice and locally about the Galice formation in the Riddles quadrangle.

These volcanic greenstones of various ages ranging through the Paleozoic and Mesozoic have been cut by numerous dikes and irregular masses of intrusive rocks of the same kind, and the whole has been so crushed, altered, and veined by later earth movements

in the process of mountain building that it would be very difficult to map them in detail separately or to determine their relative areas.

When fresh and fully crystalline the greenstone is commonly granular, like a gabbro composed essentially of pyroxene and lime-soda feldspar, but it may contain hornblende and resemble a diorite, or olivine and pass into olivine gabbro, or have ophitic structure and pass into diabase, or be compact like basalt.

Although greenstone lavas of both Paleozoic and Mesozoic age occur, the age of the intrusive greenstones is not so completely determined. Many of them may be Paleozoic, but some of them were erupted near the close of the Jurassic, and with these in the Riddles quadrangle there is some quartz porphyry that might well be called ancient rhyolite.

In southwest Oregon the ore deposits are most frequently found in greenstones.

The serpentines for the most part clearly cut the great masses of greenstone. This is best illustrated in the Galice-Kerby region (Pl. VI), where they have much to do in producing ore deposits in the associated greenstone, although the serpentine itself rarely contains bodies of ore except copper.

Serpentine is derived chiefly from the alteration of peridotite, an intrusive rock that is composed for the most part of olivine with considerable pyroxene, usually enstatite, and small crystals or grains of magnetite and chromite. With the increase of olivine or pyroxene the peridotite passes on the one hand into dunite and on the other into pyroxenite. Much of the rock in the area mapped as serpentine is peridotite in which the alteration to serpentine is not far advanced. By the miners, however, all such rocks are regarded as serpentine.

Some of the serpentine appears to show transition to gabbro, as if derived from olivine gabbro and not from peridotite intruded in the greenstone. Such serpentine has no mineralizing influence on the adjacent greenstone.

The granodiorite of southwest Oregon is well illustrated by that about Grants Pass and Williams Creek, which extends northeast by way of Evans Creek to Umpqua River. It is granular in texture and includes rocks which vary considerably in composition. The more acidic forms approach the granites and the more basic ones include quartz diorite. These rocks are composed chiefly of feldspar, quartz, and hornblende or mica, or as is most common both hornblende and mica. The color varies, depending on the amount of dark-colored minerals present, but the prevailing color of the fresh rock is dark gray. The feldspar is chiefly plagioclase which belongs to the acidic end of the soda-lime series. It is generally present in greater amount than the quartz. Most of the mica is biotite, but muscovite also is found, and in places both are present. Apatite, magnetite, and

locally garnet are accessory minerals. Granodiorite generally occurs in masses many miles in extent. Mines are not common within its area or along its border, except in such localities as Granite Hill and the rich pockets to the northeast, where granodiorite is in contact with both serpentine and greenstone.

Dike rocks are not generally abundant in southwest Oregon but are more common in serpentine areas than elsewhere. They have a wide range in composition and structure, from dacite porphyry to camptonite and augite andesite. Some of the last-named rock appears to have altered to greenstone.

The dacite porphyries are thought to be closely related genetically to the granodiorite. They have a rather sparse distribution, occurring as small knoblike areas and as dikes cutting the serpentine as well as the slates of the Galice formation at Almeda and near the Rand. The porphyritic structure is prominent in much of the rock, being due to conspicuous crystals of plagioclase, rounded grains of quartz, and rather sharp crystals of hornblende. Not uncommonly, however, the rock is without porphyritic structure, and pyroxene, amphibole, and biotite are absent. A rock of this type cuts the serpentine at the Alta mine on Josephine Creek, near Kerby. The dike is impregnated with pyrite and is being mined and crushed.

The groundmass of this rock where most siliceous is composed chiefly of fine granular quartz and feldspar, but in others places hornblende becomes more and more abundant until the rock appears to pass into a camptonite. The basic forms are less likely to be associated with ore deposits.

The latest dike rock seen in southwest Oregon is augite andesite, a dark-colored hard rock that in the form of small dikes cuts greenstones and granodiorite as well as the Horsetown formation of the Lower Cretaceous. It occurs chiefly on the eastern side of the Klamath Mountains, near the Cascade Range.

The relative age of the igneous rocks in southwest Oregon, aside from the Paleozoic and Mesozoic greenstone lavas, is fairly well established. The greenstones are the oldest, followed in order by the serpentine (peridotite), granodiorite, dacite porphyry, and augite andesite. Although some of the greenstone lavas and perhaps also some of the intrusive greenstones are Paleozoic, the bulk of the intrusive rocks, including greenstone, granodiorite, peridotite, and dacite porphyry, belong about the close of the Jurassic.

STRUCTURE.

The strata older than the Cretaceous strike generally northeast and southwest, parallel to the rock belts, and their dip for the most part is to the southeast, though in many places they are vertical.

From the position of the strata alone it appears that those in the northwest portion should be the older and that they should decrease in age to the southeast. Just the reverse, however, is the case, as is shown on the map (Pl. VI) and in the section (fig. 4).

Except the overlapping Tertiary and Cretaceous, the youngest rocks, Jurassic, are on the northwest, and the oldest rocks, the mica schists, are on the southeast, with the Paleozoic between.

This apparent reversal of the natural order is due either to folding and overturning of the strata or to faulting, by which the older rocks are made actually or apparently to overlie the younger. Both folding and faulting very probably have contributed to the complex structure of the region, but the part played by each is not as yet understood and will require detailed investigation.

The most evident line of faulting noted in the region crosses it northeast and southwest in the vicinity of Waldo and Kerby, where the Jurassic strata, as shown in figure 4, appear to pass beneath the Devonian. In figure 2 (p. 11) the approximate position of this fault is shown by the boundary between the Paleozoic and Jurassic.

A similar line of displacement may occur in the southeast portion of the Applegate region, on the California line between the Paleozoic rocks and the mica schists, but the evidence thus far observed is not conclusive.

Both of these supposed lines of faulting have been traced, mainly by Hershey, southward through the Klamath Mountains.

MINERAL PRODUCTION OF SOUTHWESTERN OREGON.

From its earliest history Oregon has been known as a region of important mineral resources. In a general way its metallic mineral production comes from two portions of the State—the Blue Mountains of northeast Oregon and the Klamath Mountains of the southwestern portion of the State

Oregon was organized as a Territory in 1848, when its rich placers were beginning to attract wide attention. No record was kept of its precious-metal production in early days, but important estimates have been made by R. W. Raymond and the Director of the Mint, who report[1] that the gold and the silver from Oregon deposited at the United States mints and assay offices from the time of their organization to June 30, 1882, amounted to $16,816,275.39 in gold. From 1882 to 1899, inclusive, Oregon produced $22,582,422.41 in gold, of which $5,808,831.11 came from the southwest portion of the State.

Only within the last decade have more complete and reliable records been available, and they are given in the following table. From 1900 to 1912, inclusive, Oregon produced $15,663,258 in gold

[1] Rept. Director of Mint, p. 44, 1882.

alone, and of this amount approximately $5,448,941 came from southwest Oregon.

The total gold production of Oregon from 1848 to 1912, inclusive, appears to have been $55,061,956. The gold production of southwest Oregon before 1881 can not be very closely estimated, but beginning with that year to 1912, inclusive, the production has been $11,257,772.

During the period from 1903 to 1912, inclusive, the placer mines of southwest Oregon produced $2,014,715 in gold and the lode mines $1,523,226. Besides this in the same time the production of silver was valued at $63,385; of platinum, $15,293; and of coal, $2,602,122. Considerable copper was also produced.

Gold and coal have always been the most important mineral products, and except in 1910 the value of the gold exceeded that of the coal. Definite statistical data concerning copper, quicksilver, and limestone are not available for most of the period under consideration.

Value of the mineral products of southwest Oregon, from 1900 to 1912, inclusive, compared with the total gold production of the State for the same period.

Year.	Total gold production of Oregon.	Southwest Oregon.					
		Gold.			Silver.	Platinum.	Coal.
		Total.	Placer.	Lode.			
1900	$1,694,700	....	....	....	....	....	$220,001
1901	1,818,100	....	....	....	....	....	173,646
1902	1,816,700	....	....	....	....	....	160,075
1903	1,290,200	$531,631	$297,371	$234,260	$14,278	....	221,031
1904	1,412,186	504,163	250,132	254,031	482	$1,912	243,588
1905	1,405,235	364,900	179,480	185,420	5,348	2,000	282,495
1906	1,366,900	600,000	289,560	310,440	14,551	....	212,338
1907	1,129,261	396,478	239,942	156,536	4,085	....	166,304
1908	865,076	250,664	193,484	57,180	4,229	836	236,021
1909	781,964	274,245	185,252	88,993	2,609	4,940	235,085
1910	679,488	209,324	130,103	79,221	1,204	1,121	235,229
1911	633,407	188,971	123,008	65,963	6,256	3,265	108,033
1912	770,041	217,565	126,383	91,182	10,343	1,219	108,276
	15,663,258	3,537,941	2,014,715	1,523,226	63,385	15,293	2,602,122

LODE MINES AND PROSPECTS.

GOLD-QUARTZ LODE MINES.

GENERAL FEATURES.

The diverse stresses and consequent earth movements involved in the development of the Klamath Mountains have resulted in widespread crushing and shearing of the rocks, but the fissuring was general instead of being concentrated in narrow belts. The final veining of the rocks and the accompanying ore deposition in general formed many small though commonly rich ore bodies instead of a few larger ones. This condition has greatly encouraged prospecting and led to the development of a multitude of small lode mines. Placers, too, are abundant on many streams and have guided the search for

ore bodies. In fact they afford one of the best indications of the whereabouts of lodes in residual material.

Many mines and prospects, some of which have produced only a few hundred dollars, others thousands of dollars, and a very few as much as $100,000, are now lying idle. At present some development work is in progress on new prospects and in mines which have until recently been closed, as well as in the mines that have been producers for some years. The total production of the 22 lode mines of southwest Oregon reported in 1910 was $79,221, as compared with $130,103, the output of 64 placer mines of the same region during the same year.

The gold-bearing quartz is widely distributed and occurs in small veins, veinlets, and brecciated zones in several kinds of rock. Most of the mines and prospects are situated in the greenstones, but some lie in the granodiorites, some in metamorphosed sediments, and a few prospects in peridotites or their decomposition product, serpentine.

A striking feature of many of the gold-bearing veins is that they are found in proximity to serpentine. This is well illustrated in the general distribution of the mines of the Galice-Kerby region, as shown in Plate VI. Usually, however, the veins are cut off sharply at the contact and the ore rarely extends into the serpentine. This may be due in some measure to faulting, for the distribution of the serpentine suggests that the hydrothermal action consequent on the intrusion of the peridotite resulted in the deposition of the vein matter.

The ores are found in several relationships in these rocks. In some places they occur in greenstones at considerable distances from other kinds of rock; in others they are in the greenstones but at the contact with or near to granodiorites and related rocks. Some veins are parallel to the schistosity in the greenstones. Again, some veinlets occur in both greenstones and sediments, and in such places it is not unusual to find rich ores near the contact of these rocks and closely related to dikes which cut them. This relationship of the rich ore to dikes is also shown where the veinlets lie in the sediments only. In the peridotites some of the veinlets are present at the contact with or near dikes related to granodiorites.

Many of the veins and veinlets have never produced important bodies of ore but only "pockets," some of which, although filling but small spaces, were remarkably rich, the gold usually having been coarse. In general most of the gold in these pockets has been taken from depths less than 25 feet from the surface.[1]

The veins and veinlets run in all directions. However, a comparison of the more persistent of them showed that more lie in an east-west direction than in a north-south direction. The dips of the veins vary greatly; most of them have fairly high dips, but some are nearly

[1] As to the origin of "pockets" in the Klamath Mountains, see Ferguson, H. G., Gold lodes of the Weaverville quadrangle, California: U. S. Geol. Survey Bull. 540, pp. 40-43, 1914.

flat and some are vertical. The widths of the veins are generally less than 1 foot; a great many are considerably less, and in some places they form an intricate network of stringers. On the other hand, some veins are more than 10 feet wide. Such veins are either separated into several parts by "horses" or there is a decided brecciation of their materials. In one of the best mines in the region, the Greenback, the average width of the vein is 18 inches.

The vein filling consists mainly of quartz, which is usually of a milky-white color. Many of the veins contain quartz crystals with perfect outlines, indicating that the deposition took place in open fissures. Calcite is commonly found with the quartz, and subordinate amounts of sulphides, chiefly iron pyrites, but not uncommonly arsenopyrite, chalcopyrite, and galena are also present. A few of the veins contain pyrrhotite. The sulphides rarely exceed 3 per cent of the ores. Telluride ores are reported from a number of mines, and samples of undoubtedly rich telluride ores were exhibited as coming from those mines, but the writer did not see any of this ore in place.

A study of the fillings of the veins in different kinds of rock suggests that the nature of the country rock has not influenced the contents of the fissures to any appreciable extent. The gold is present as free gold in the quartz and is also associated with the sulphides and tellurides, some of the concentrates being rich.

Little gold has been found in the country rocks adjacent to the veins. These rocks in some places are only slightly altered, but in other places they have been chloritized and in still others the products of alteration consist of carbonates, albite, quartz, and pyrite. The presence of albite rather than sericite, a common mineral in the wall rocks of the gold-quartz mines of California,[1] is no doubt due to the fact that the Oregon rocks, as indicated from the analyses thus far made, are considerably richer in sodium than in potassium.

The lower limit of the zone of oxidation is in general less than 100 feet below the surface, but in places it exceeds 200 feet.

In the Bohemia region the gold-bearing quartz veins, being in Tertiary lavas, are evidently of later age. In some other localities in Oregon the quartz veins may be younger than the earlier Cretaceous but older than the Eocene. By far the greater portion of the vein filling and ore deposition in southwestern Oregon took place about the close of the Jurassic and the beginning of the Cretaceous.

BLUE RIVER MINING REGION.

Very little is known of the Blue River mining region, although it has kept up a small production for many years. A very brief account of this district was given in my report on the Bohemia mining region.[2]

[1] Lindgren, Waldemar, Am. Inst. Min. Eng. Trans., vol. 30, p. 665, 1901.

[2] Diller, J. S., The Bohemia mining region of western Oregon: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 31, 1900.

The Blue River region lies on the western slope of the Cascade Range, near McKenzie Fork, about 45 miles east of Eugene. It is 50 miles a little east of north from the Bohemia region, and its rocks, like those of that region, are wholly igneous and of comparatively recent origin. The rocks differ, however, from those of the Bohemia district in being generally more siliceous, although both andesites and basalts occur. Rhyolite is common, especially on the slope of Gold Hill, where much of it is so conspicuously banded as to be mistaken for a stratified rock. Some of the prospects lie in altered andesite. The summit of Gold Hill is capped by well-marked basalt, very rich in olivine.

Many claims have been opened up, but as yet that of the Blue Bird Mining Co. appears to be the most active. The company is the only one in the Blue River region reporting a production in 1910 and continued to operate in 1912.

The veins of quartz contain pyrite, some of which is reported to be highly auriferous. Sphalerite and galenite are less abundant than in the Bohemia district. The veins strike N. 60°–88° W. and dip 75°–9° SW., approximately parallel to those of the Bohemia region, and it may be inferred that they originated in practically the same earth movement.

BOHEMIA MINING REGION.

The Bohemia mining region lies on the crest of Calapooya Mountain, a shoulder that juts out from the western slope of the Cascade Range and forms the divide between Willamette and Umpqua rivers as well as the boundary line between Lane and Douglas counties. The region is 30 miles southeast of Cottage Grove on the Southern Pacific Railroad, as shown in figure 5, and may be reached by a branch railroad to Disston and 12 miles of staging to Champion. Two reports on this mining district have been publishd by the Geological Survey.[1]

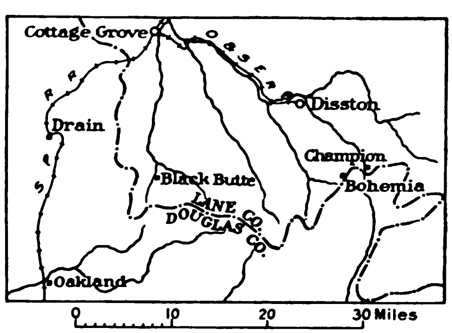


FIGURE 5.—Map of the Bohemia mining region, showing its accessibility by the Southern Pacific Railroad.

The Bohemia region is one of special interest. Its ore deposits, occurring in the Tertiary lavas of the Cascade Range, are apparently the latest formed in southwest Oregon. They lie in the line of the most northern mineralized belt in Curry and Douglas counties.

[1] Diller, J. S., The Bohemia mining region of western Oregon: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 7–36, 1900. MacDonald, D. F., Notes on the Bohemia mining district, Oregon: U. S. Geol. Survey Bull. 380, pp. 80, 84, 1909.

The following description is taken directly from Mr. MacDonald's publication:[1]

PHYSIOGRAPHY AND GENERAL GEOLOGY.

The relief of the district is pronounced. Several peaks are more than 6,000 feet high and the elevation of the lowest valleys is less than 2,000 feet. This bold relief is the result of mountain glaciation and stream erosion. The luxuriant vegetation due to the humid climate has somewhat masked the geologic features of the region. Great forests clothe the mountain slopes and the region is notable for its timber value.

The rocks of the district are andesitic lavas and tuffs of Tertiary age which are cut by dacite porphyry and probably by basalt. The andesites are the most abundant rocks. Seven consecutive flows aggregating 500 feet in thickness appear on the south face of Bohemia Mountain. They vary from light to dark gray in color and in hand specimens show small elongated phenocrysts of feldspar and very small greenish crystals of pyroxene or chlorite. In weathering the rock assumes a light-gray to buff color, the feldspars becoming white and powdery. Good exposures of andesite are shown on Bohemia, Elephant, Fairview, and Grizzly mountains.

The tuffs, in the main, are of andesitic composition and at many places are interbedded with andesite flows. A tuff composed of coarse fragments occurs near the White Ghost claim on City Creek. Fine tuff interbedded with lava is shown in the crosscut to No. 2 level in the Noonday mine. The slope east of Horseheaven Creek shows a considerable area of light-gray stratified tuffs. Fine gray banded tuffs were seen on the slopes below Judson Rock. These tuffs are contemporaneous with the andesites, particularly with the later flows.

A light-gray rock, probably dacite porphyry, cuts the darker andesites and tuffs in many places. This rock on fresh fracture shows minute aggregations of quartz, larger crystals of feldspar, and small dark crystals of pyroxene and hornblende. The fine groundmass between the large crystals is gray to slightly greenish, the green tinge being due to the presence of chlorite. This dacite porphyry cuts andesites and interbedded tuffs at several places along the road about halfway between Disston and Orseco. It also occurs within half a mile of the Musick mine, both to the northeast and to the southeast.

Basalt occurs in one or two small outcrops. It is a fine-grained dark lava, best shown on the south edge of Bohemia Mountain, Its small outcrop suggests that it is intrusive in the andesite.

ORE DEPOSITS.

The ore deposits of this district are fissure veins, which cut the andesites and tuffs. Small sulphide impregnations also occur in the vicinity of altered diabasic dikes, but they have no economic value. The general strike of the veins is north to northwest, with a dip of 60° to 85°. They vary from 1 foot to 12 or 15 feet in width. Some are single veins; others consist of two or more parallel veins, separated by a few inches to a few feet of highly altered country rock. At the Musick mine there are three parallel veins, 1 to 4 feet in width, separated by thin walls of altered country rock. Only the fissure veins which have suffered postmineral fracturing have produced profitable ore. These veins, because of their oxidized and easily workable condition, gave good returns in free gold in their upper workings. Veins which have not been fractured since they were mineralized, or which are situated in regions of maximum erosion, such as old glacial cirques, show sulphide ores at the surface. They are tightly cemented and relatively impermeable and represent the conditions of mineralization that prevail in all the veins below the oxidized zone. The minerals which they contain are sphalerite, pyrite, a little galena, and very little chalcopyrite, with a gangue

[1] U. S. Geol. Survey Bull. 380, pp. 80-84, 1909.

of quartz, altered country rock, and some calcite. So far these veins have not been found profitable, because their sulphide ore can not be cheaply treated, the tightness with which the ore is cemented makes mining more expensive, and the gold tenor is less than that of the oxidized material.

HYDROTHERMAL METAMORPHISM.

In the vicinity of the veins the mineralizing solutions have greatly altered the country rock. Several hundred feet distant from a vein the dark color of the rock is in many places changed to a greenish tinge, while close to the deposit it is gray to buff in color, has a clayey appearance, and crumbles easily. The pattern of the rock is fairly well preserved, however, the outlines of the feldspar phenocrysts being clearly visible, though the feldspar material has been changed to a white or yellowish powder.

Under the microscope it is seen that the basic feldspars have altered into sericite, calcite, and quartz, the quartz, however, being in relatively small quantity. The ferromagnesian minerals have been changed to calcite, and the iron in them appears now as limonite or hematite. Farther away from the vein, where metamorphism was less intense, these minerals have reached only the chloritic stage of alteration. In many veins soft disintegrated country rock forms a considerable part of the vein matter. An examination of this material showed that near the surface it is composed essentially of very fine granules of quartz with considerable iron-stained kaolin. At greater depth the same rock contains an abundance of sericite and calcite with very little kaolin.

SECONDARY ALTERATION AND ENRICHMENT.

Some of the veins were brecciated after they were filled, and as a result oxygenated waters were able to percolate downward along the fractured zone. The ores were thus oxidized and sulphides leached out to depths of 100 to 300 feet, depending on the degree of brecciation and the rate of erosion. The gold occurred as threads and filaments included in the pyrite. The pyrite was leached away, leaving the relatively insoluble gold and some iron oxide occupying a part of the small cavity left in the vein material. This process brought about an association of free gold with iron-stained, spongy quartz, and enriched the ore by leaching out the valueless sulphides. It also rendered the ore soft and porous, so that it is much more cheaply mined and milled than the unaltered ore.

Small local enrichments of free gold occur at the junctions of fissures, pyrite being abundant at these junctions, as shown by the mass of iron oxide left. It is probable that the smaller particles of gold were dissolved from the upper parts of the vein by the ferric sulphate solutions of oxidized pyrite and were precipitated by the local masses of pyrite below.

Some secondary sulphides were observed, but these are of no commercial value. They consist of pyrite crystals deposited in cracks in primary pyrite and of very small masses of sphalerite and galena. Other secondary minerals noted were calcite and, rarely, cerusite.

MINING DEVELOPMENT.

Gold was first discovered in Bohemia in 1858. In 1875 the first mill, a five-stamp battery, was built on the Knott claim. From 1877 to 1891 little was done in the district. In the nineties the Musick, Champion, Noonday, Vesuvius, and several other mines became active, and mills aggregating 35 or more stamps were built. At the time of visit, in August, 1908, no ore was being milled in the district, nor had any milling been done since the previous summer. Several companies, however, had men employed in prospecting and development.

Figures for the total output of the camp are not available. As nearly as can be judged from the statistics published in "Mineral Resources of the United States," and from verbal reports, the total product is probably between $300,000 and $400,000,

mainly in free gold. Although some rich shoots occur locally, the average tenor of the ore is low, generally running $3 to $5 a ton. The soft, spongy, iron-stained vein material is cheaply mined and milled. The cost of mining is from $1.50 to $2 a ton, and of milling little over 50 cents a ton. The concentrates range in value from $20 to $70 a ton and consist in the main of auriferous pyrite, with silver and a little lead and copper. Values less than $25 a ton can not be profitably shipped because of present high freight rates.

The principal mines of the region which have produced values are the Musick, Champion, Vesuvius, Noonday, Helena, and California, and there are others of lesser note. The Musick leads in development, with about a mile of drifts along six 50-foot levels. Of these, levels 4 and 6 are reached by short crosscuts which tap the vein from the basin at the head of City Creek. About 2,000 feet to the west, on the other slope of the divide, a portal from one of the lower drifts opens out close to a good stand of mining timber. A shaft 80 feet deep connects directly with the two upper levels and through various stopes with most of the lower workings, thus giving good ventilation to the mine. Most of the ore was hauled out at the lower level, which attains a maximum depth of about 300 feet.

The Champion, Vesuvius, and Noonday have each about half a mile of workings. In the Champion most of the development work has been done on two levels, the lower of which attains a maximum depth of about 200 feet and is reached by a crosscut a few hundred feet in length through which all the ore is brought out. A considerable amount of stoping has been done, particularly where the greatest oxidation occurred. The lower workings here show considerable amounts of primary sulphides. The Vesuvius has been worked from several levels to a depth of about 300 feet and has many stopes. The steep slope on which it is situated has facilitated its development by tunnels and has afforded a gravity transfer for the ore from stope to mill, as well as good ventilation and drainage for all the workings. The Noonday has three principal levels, all tapped by crosscuts from the steep slope of the Horseheaven basin; the lowest level attains a maximum depth of about 300 feet. Considerable stoping was done, and the ore from the stopes was sent down to the mill on an aerial tramway about one-third of a mile in length. The Helena has more and the California somwehat less than 1,000 feet of workings. Both are developed by tunnels which will attain 100 to 300 feet of depth. The Helena has two levels and has produced some very rich specimen ore.

The ore from the Musick mine was hauled over a practically level electric tramway about a mile in length and dumped into the ore bins of the Champion mine. Thence the ore of both mines was sent down to the mill on a steep incline, 3,400 feet long. Haulage was effected by an endless cable to which the mine cars were attached by means of an automatic grab, the loaded cars going down pulling the empties up. The Musick-Champion mill, the largest in the district, has 30 stamps and is run by a water-driven electric generating plant located on Frank Bryce Creek, 7 miles below the mine. It handled the ore from both the Musick and Champion mines. The electric plant was designed to develop 300 horsepower and to operate the stamp mill, a small sawmill, and a local electric-light plant, and to furnish mine power. A small auxiliary steam plant is provided for use in case of need. Other milling plants in the district are a 10-stamp mill at the Vesuvius mine, a 5-stamp mill at the El Calado property, and a 20-stamp mill on the Noonday group.

SILVER AND COPPER PROSPECTS.

The Riverside and Oregon-Colorado claims are promising copper prospects which show some good chalcopyrite ore and are located on strong veins. The Combination property covers a somewhat extensive lode, consisting of one large vein and some smaller veins, and is said to have produced ore which assayed more than 25 ounces of silver to the ton.

FUTURE OF THE DISTRICT.

The Bohemia district contains many well-defined veins and lodes. Many of those which show on the surface have not yet been explored, and no doubt many more are obscured by the dense vegetation which covers a large part of the district. It seems reasonable to suppose that other mines will yet be opened and will find workable gold ore, at least in the upper and oxidized portion of the veins. Workable bodies of copper and silver may possibly be discovered in the district.

In 1910 there were four producing companies in the Bohemia region. The entire output of the Bohemia district in 1912 came from deep mines, the largest producer being the West Coast mine, which is opened by a 1,000-foot tunnel and has a 30-stamp mill. It is reported as one of the large deep mines of Oregon by C. G. Yale in his preliminary estimate for 1913, but details are not yet available.

PORT ORFORD QUADRANGLE.

The placers of the Sixes River and Johnson Creek region, extending 15 miles in a direction N. 80° W. from Coos County into Curry County, have long attracted attention, and many attempts have been made to locate the source of the gold. The principal endeavors were made at Rusty Butte, Salmon Mountain, and on Poverty Gulch. Several quartz mills have been erected and small pockets found. At Poverty Gulch on Johnson Creek the work has been most persistent, one lode mine and two placers being reported in 1910, but the total output was small. The quartz veins containing free gold and auriferous pyrite are in gabbroid greenstone.

On Rusty Butte, which yielded some fine specimens of wire gold, prospects were at one time very encouraging. Some portions of the disintegrated iron-stained material contained quartz and others contained calcite, associated with pyrite, arsenopyrite, and small cubic crystals of galena.

On the northwest slope of Salmon Mountain, not far from the contact between gabbro and Mesozoic slates, auriferous quartz veins have been prospected by several tunnels, but the search has not been as successful or persistent as at Poverty Gulch on Johnson Creek, where several mines have reported a small production for years.

The principal mine on Johnson Creek some years ago was an open cut into a steep slope exposing a very ferruginous seamy quartz mass containing much black manganese oxide. It is situated on the contact of a form of dacite porphyry and slates, intermingled with other igneous rocks which the dacite porphyry intersects.

The black oxide of iron and manganese interferes mechanically to a considerable degree with the amalgamation of the gold. The east-west dike of dacite porphyry has doubtless had much to do with the mineralization of the Johnson Creek region. In 1912 Curry County produced placer gold to the value of $12,786, besides 39.91 fine ounces from lode mines.

ROSEBURG QUADRANGLE.

The Roseburg quadrangle lies in the middle portion of Douglas County and includes, in the mining region of Myrtle Creek, the only lode mines between the Bohemia region on the north and the Riddles quadrangle on the south.

The Myrtle Creek region has not been visited by geologists of the United States Geological Survey within the last 10 years. Only one producing mine was reported in 1910. The earlier developments were by placer mining in disintegrated gabbro that carried small auriferous quartz veins, but the later production has been reported chiefly from lode mines. The total production of gold in Douglas County in 1912 amounted to 684.07 fine ounces, or 25.64 ounces more than that of Curry County. Of this quantity 539.91 fine ounces came from the placers.

RIDDLES QUADRANGLE.

MINING CONDITIONS.

The northern half of the Riddles quadrangle (see fig. 1, p. 10) is in Douglas County and the southern half is almost equally divided between Jackson and Josephine counties.

The location of the principal mines and prospects of the Riddles quadrangle in 1907 is shown in figure 6, and their descriptions are chiefly as given by Prof. Kay.

Much prospecting for gold quartz veins has been done during the last 15 years within the area of the Riddles quadrangle. Comparatively few important discoveries have been made, but, although some of the mines are no longer producing, others, once idle, have resumed work and become important producers. Some of the principal mines are described below.

GREENBACK MINE.

The Greenback mine, once the largest producer in southwest Oregon, has again obtained that distinction. It is situated on Tom East Creek, a branch of Grave Creek. On the same stream, a little farther down, is the Columbia placer mine, which is one of the largest in the State.

The Greenback was discovered in 1897 by two prospectors who lived in the vicinity of Placer, on Grave Creek. They worked the deposit for about a year, treating the ore with an arrastre at Placer. They then sold the property for $30,000 to the Victor Junior Gold Mining Co., and Messrs. Moffatt & Smith, of Denver. In 1902 more than 90 per cent of the stock was purchased by Mr. Brevort, and the corporation was named the Greenback Gold Mining & Milling Co. No transfer has since been made.

From the time when the property came into the possession of the Victor Junior Gold Mining Co. until 1906, the development of the mine was rapid, more equipment being added each year. At first a 5-stamp mill was installed, later 5 stamps were added, and in 1902, when Mr. Brevort became the chief owner, there were 15

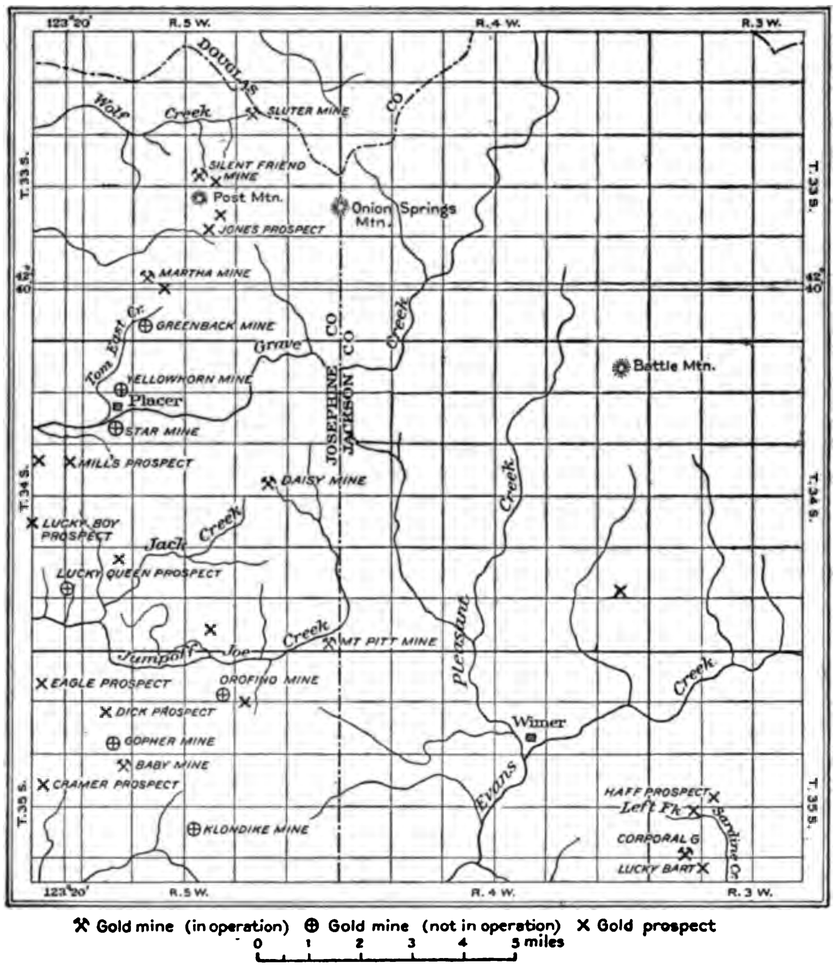


FIGURE 6.—Map of part of the Riddles quadrangle, showing the most important gold-quartz mines in 1907.

stamps, besides a crusher, an air compressor, and three Wilfley tables for concentrating. Mr. Brevort's company soon began the construction of a new mill, about a quarter of a mile farther down the stream. At first 20 stamps were used in this mill. This number was increased until, in 1905, 40 stamps were being used. The new plant has three large Risdon crushers and 12 concentrating tables. There

is also a cyanide plant, consisting of four large tanks, with a capacity of 100 tons a day. For a while the mill was equipped with both steam and water power, but in 1905 a complete electric system was installed. The power was brought, by way of Grants Pass, from the Ray dam on Rogue River, a distance of about 30 miles. In August, 1906, work at the mine was suspended, but it was resumed before 1910.

The workings of the mine are extensive, consisting chiefly of crosscut tunnels to the vein and drifts and shafts on the vein. Much of the ore has been stoped along the whole length of the vein to a depth of about 1,000 feet from the surface. The lowest workings are on the twelfth level.

The country rock is greenstone, which is considerably metamorphosed, but which, where most free from alteration, resembles a gabbro. To the east and southeast of the mine a considerable area of serpentine is present, and a short distance to the north lies the southwestern limit of a band of siliceous slates which extends for some miles to the northeast.

The Greenback vein has a direction almost east and west and dips in general about 60° N. It averages about 18 inches in width but ranges from less than 6 inches to more than 4 feet. A crushed zone of quartz stringers and country rock, forming in places a beautiful breccia, is present where the vein is widest. The country rock of the breccia is strongly chloritized and contains sulphides which carry gold. In many places the foot and hanging walls of the vein are fairly definite, but where considerable brecciation has occurred there is no distinct boundary between the vein material and the chloritized country rock. The vein is cut off sharply to the east against serpentine and to the west by a fault. Between the serpentine and the fault plane the vein has an average length of more than 500 feet and within this distance there are only minor displacements. The vein has not been picked up to the west beyond the fault plane, nor has it been found in the serpentine to the east. This latter fact tends to prove that the rock from which this serpentine was derived was younger than the vein, rather than that the present relations are due to displacements between the greenstone and its decomposition product, the serpentine, as is indicated in some places in the quadrangle.

The vein filling consists of quartz, calcite, and pyrite, which vary in amount in different parts of the vein. The average content of the ore mined from the first and second levels was between $8 and $9 to the ton; a few assays on these levels ran above $40 to the ton. Capt. Buck states that over 75 per cent of the gold was free milling. The concentrates ran about $75 to the ton and after cyaniding the ores contained less than $1 to the ton. Within the mine there is but little evidence of oxidation of the ores, except near the surface.

The Greenback mine was reported as operating in 1912. Its plant has a maximum capacity of 100 tons a day.

A short distance south of the Greenback vein and running almost parallel to it is the Irish Girl vein, on which very little work has been done.

MARTHA MINE.

The Martha mine is in the SW. ¼ sec. 28, T. 33 S., R. 5 W., about 1¼ miles north of the Greenback. It was purchased by the Greenback Co. in 1904 and somewhat extensively developed. The electric power of the Greenback was extended to this property, and in 1906 an aerial tramway, said to have cost $20,000, was constructed to connect the two mines. For a few months the ore of the Martha was conveyed by the tramway to the Greenback plant and treated there. The company also installed a 75-horsepower air compressor. When the Greenback was closed the company also stopped all work at the Martha, but since then both mines have resumed work.

The mine was prospected by four tunnels whose length aggregates nearly 3,000 feet. At the time the property was examined (June, 1907) it was leased by J. M. Clarke, of Golden, Oreg., who had brought in five stamps and was treating the ore which had been mined by the Greenback Co. but which had not been shipped to the mill.

The country rock is greenstone. The ores resemble those of the Greenback but do not carry as much gold. They occur in narrow veinlets and stringers in zones of shearing and brecciation, which have a general trend between northwest and west and a range in width from a few inches to more than 4 feet.

BABY MINE.

The Baby mine is situated in the northwest corner of sec. 16, T. 35 S., R. 5 W., and is owned by the Capital City Gold Mining Co. The property was located in 1897 and since that time has been extensively developed by its present and former owners. It is now leased by R. S. Moore, of Grants Pass. During the summer of 1907 three stamps were in operation, but they appear to have ceased before 1910. Mr. Adams, the manager of the company, says that the mine has yielded gold to the value of more than $20,000.

The equipment comprises a 5-stamp mill, two boilers, a concentrating table, and a small crusher. The development consists of more than 1,500 feet of tunnels, shafts, drifts, upraises, and crosscuts.

The vein occurs in greenstone and averages about 4 feet in width, but in places becomes a fissured zone more than 10 feet wide comprising many parallel stringers of quartz which carry gold. The vein ranges in direction from northwest to nearly west and dips northeast, generally at high angles, although in some places it is almost vertical and in others almost flat.

A striking feature of the mine is the prevalence of faults, which are not only numerous but vary considerably in direction and in amount of displacement. One of the most prominent of the fault planes runs S. 80° W.

The vein material consists of a somewhat sugary-looking quartz, some calcite, and some pyrite. The gold is carried chiefly by the quartz; in many parts of the vein free gold may be seen with the unaided eye. The sulphide varies in amount in different parts of the vein and when concentrated yields about $75 worth of gold to the ton.

SILENT FRIEND MINE.

The Silent Friend property lies in the southern part of sec. 15, T. 33 S., R. 5 W., on the north slope of Post Mountain. It is owned by the original locators, John Scribner and George Henderson, both of Speaker, Oreg. They discovered the vein in 1900, worked it until 1902, and then leased it for 18 months to Joseph Dysert. From the expiration of this lease until August, 1906, no development was carried on, but for some time after that date the owners worked the mine on a small scale. Mr. Scribner states that from the oxidized material on the surface, overlying a network of small stringers, he has taken gold to the value of more than $7,000.

The chief development has been by two tunnels, the lower of which is 320 feet in length and crosscuts several small stringers. The upper tunnel is 75 feet in length and has an upraise to the surface.

The country rock is greenstone, which is strongly chloritized adjacent to the veins. The chloritization is no doubt due to the action of the mineral-bearing solutions. The ores are found in veinlets and stringers which run in various directions, but the majority of them have a general trend between southwest and west.

The filling consists of quartz, calcite, pyrite, arsenopyrite, and locally chalcopyrite. Some specimens of ore, which were found to consist largely of calcite, chlorite, and arsenopyrite, contained considerable free gold visible to the unaided eye. These specimens, which were taken from the bottom of one of the drifts, appeared to represent in the mine the ore of an 18-inch brecciated zone, which could be followed for several feet.

DAISY MINE.

The Daisy mine, which is situated on the divide at the head of Jack Creek, is on one of six claims that constitute the Oregon Mohawk gold mines, owned by G. R. Smith, of Grants Pass. It was discovered in 1890 and for a time was worked under the name of the Hammersley mine. Then the stock was acquired by Morton Lindley, of San Francisco, who later disposed of it to the present owner.

Preparations were being made during the summer of 1907 to pump the water from the mine, which had been idle for some time, and

mining operations were to be resumed. Mr. Smith stated that the mine had produced gold to the value of more than $200,000.

The workings consist of an inclined shaft 175 feet in depth, from which, at 115 feet below the surface, a drift runs along the vein for 350 feet to the west and 50 feet to the east. All the ore above has been stoped. From the bottom of the shaft a drift runs eastward on the vein for 140 feet and westward for 243 feet.

The veinlets of gold-bearing quartz carrying pyrite run about east and west and are in a chloritized greenstone. The ore-bearing zone has a width of about 3 feet.

MOUNT PITT MINE.

The Mount Pitt mine is situated in the southeast corner of sec. 36, T. 34 S., R. 5 W. It was located by H. G. Rice, of Grants Pass, the present superintendent. The property is owned by A. C. Hooper, of Portland.

The present workings consist of an entrance tunnel of 225 feet to cut the vein, a drift of 100 feet along the vein, and an upraise of 200 feet from the drift to the surface. A mill has recently been erected, containing a crusher, an automatic feeder, 5 stamps, and a concentrating table.

The ore is found in small irregular veins in sheared greenstone, the sheared zone being usually about 3 feet wide. The quartz veins are rarely well marked, the greatest width of quartz seen being 4 inches, and this is not persistent for more than a yard or so. The quartz veinlets are in general parallel to the plane of shearing, but some of them are small cross gash veins nearly horizontal.

OROFINO MINE.

The Orofino property, which is located in sec. 3, T. 35 S., R. 5 W., has been closed for several months, and the workings are beginning to cave. The present owners are Messrs. Monahan & Mason, of Seattle. The last work was done by B. F. Chase, of Portland, who had a lease.

C. D. Crane, of Grants Pass, stated that nearly 2,000 feet of work had been done on this property. Fourteen carloads of ore have been shipped to smelters at Tacoma, Wash., and Ashland, Oreg. At one time the mine had considerable equipment, including a 2-stamp mill, cyanide tanks, rock crushers, boilers, and hoists, but much of this material has been sold and shipped away.

The ore occurs in veinlets and stringers in a much fractured, brecciated, and chloritized greenstone. Many of the fragments of country rock of the breccia contain considerable pyrite. The vein filling consists chiefly of quartz and calcite, and, as shown by the relations of the two, the calcite was deposited later than the quartz. Sulphides

are also present in some parts of the vein in considerable amounts, but in other parts they are almost entirely absent. A large amount of ore is now lying on the dump, and many sacks of ore are ready for shipment.

OTHER MINES IN THE GREENSTONE AREAS.

All the mines thus far described are associated with greenstones and the descriptions indicate that the character of the ores and their modes of occurrence are very similar. Many other mines and prospects associated with the greenstones might be described, but they would show few new features. Some of these, as for example the Gold Leaf and the Black Diamond in the Cow Creek region, are now being developed and producing; some have been extensively prospected but have never produced; others have, in the past, produced small amounts but are no longer being worked. Among such mines and prospects may be mentioned the Lucky Queen, Mill's prospect, Star mine, Olympic prospect, Spotted Fawn prospect, Blalock & Howe mine, Eagle prospect, Cramer prospect, Gopher mine, Trust Buster, and Dick prospect, most of which are indicated on the map (fig. 6, p. 32). To the north of the area shown on the map are the Gold Bluff and Levens Ledge mines, both near Canyonville.

CORPORAL G MINE.

Of the mines which are not associated with the greenstones but with metamorphosed sediments the chief are the Corporal G mine and the Lucky Bart group, which lie west of the Left Fork of Sardine Creek.

The Corporal G mine is located in the southern part of sec. 19, T. 35 S., R. 3 W. It was discovered in 1904 by J. R. McKay, who, after taking out considerable rich ore, sold it to Mrs. Nina M. Smith, of Gold Hill, the present owner. The property is now leased by J. E. Kirk.

The workings consist of three tunnels, one above another, on the vein. The longest tunnel is 92 feet in length, the shortest 63 feet. The ore occurs in a small vein which has fairly definite walls of micaceous quartzite and mica slate. The average width of the vein is about 7 inches; it strikes S. 85° W. and dips steeply to the north. The filling consists chiefly of quartz and calcite, but pyrite, pyrrhotite, chalcopyrite, bornite, sphalerite, and galena are also present. A few of the hand specimens show free gold.

Close to the Corporal G is the Volunteer claim, on which a stringer running parallel to the Corporal G was followed by a drift for 135 feet, where it pinched out. This stringer intersects a barren cross vein running about N. 30° E.; at the intersection the ore in the stringer is said to have been enriched.

LUCKY BART GROUP.

The Lucky Bart group consists of 11 claims in the NW. ¼ sec. 29 and the SE. ¼ sec. 30, T. 35 S., R. 3 W. The chief claim, the Buckskin or Lucky Bart, was discovered by Joseph Cox, who sold it in 1892 for $15,000. This amount he had to share with his partner, Bart Signoretti, who had had no part in the discovery, hence the name Lucky Bart. The company which bought the property worked it four years, when one of the shareholders, J. H. Beeman, of Gold Hill, purchased the rights of his associates and became the owner. About the same time Mr. Beeman purchased adjoining claims until he had title to all the property included in the Lucky Bart group. At present mining operations are being carried on at only one of the claims, the Yours Truly. The workings on the other claims, mainly on the Lucky Bart, are in such condition that it is unsafe to enter them. The only workings examined were those of the Yours Truly. Information with regard to the other workings of the group was obtained from J. H. Beeman and J. E. Kirk. The Lucky Bart group was reported as operating in 1912.

Ore has been mined from five veins which run in a general direction a little south of west. These veins are on the average less than 2 feet wide. The country rock is metamorphosed sediment, mainly mica slates and micaceous quartzites. The general strike of these rocks in this vicinity is somewhat east of north; the dip is to the southeast and is in general at fairly high angles. The total amount of ore that has been milled exceeds 14,000 tons, which yielded from $4.80 to $100 a ton of free-milling ore. The ore from the Lucky Bart claim carried an average of 3 per cent of sulphides, which ran from 4 to 8 ounces of gold to the ton and a like amount in silver. Nine tons of ore from the deepest workings of this claim were shipped to the Tacoma smelter and gave returns of $130 to the ton. Practically all the ores from the group have been treated at a mill on Sardine Creek; the sulphides were shipped to the smelters at Tacoma, Wash., and Selby, Cal.

At the Yours Truly, where work is now being done by J. E. Kirk, who has a lease on the property, the workings consist of an entrance tunnel of 75 feet to the vein, 100 feet of drifting on the vein, and a shaft of 30 feet. The country rock is mica slate. The vein has an average width of about 1 foot and strikes S. 85° W. At the end of the drift there are two veinlets, 8 inches and 4 inches in width, and also a small seam. Within the workings there is evidence of considerable faulting. The directions of the fault planes observed were somewhat east of north. Mr. Kirk states that the veins carry more gold adjacent to the fault planes than elsewhere. The ores of the Yours Truly are highly oxidized and carry an average value of more than $30 to the ton.

CONCLUSIONS.

Of the many veins and veinlets within the Riddles quadrangle on which work has been done, comparatively few have been developed into profitable mines. The chief reason is to be found in the structural features of the rocks in which the ores occur. The Paleozoic and early Mesozoic sediments with their associated igneous rocks were, previous to the mineralization of the region, subjected to earth movements of such a nature that no definite, continuous fissures were formed but rather, in general, innumerable minute and irregular fractures running in various directions. Later, when the mineral-bearing solutions, which may have been connected with one or more of the igneous intrusions, passed through these rocks and deposition therefrom took place, the gold was not concentrated in definite lodes but was widely distributed through the rocks in small veins, veinlets, and stringers, few of which are continuous except for short distances. Furthermore, in many places where fairly distinct and rich veins were formed subsequent faulting has been so prevalent that it is difficult and costly to find the continuations of the veins. Notwithstanding these unfavorable conditions, however, the gold-quartz veins have produced and will probably continue to produce considerable amounts of gold. The hope of finding vein deposits which will develop into large and profitable mines is stimulated by the reopening of the Greenback and Martha mines.

The veins and veinlets have been subjected to erosion for many thousands of years, during which time an immense amount of material has been freed of its gold. Much of this gold has been deposited in the neighboring streams, from which it has been and is being mined as placer gold.

GRANTS PASS QUADRANGLE AND MEDFORD DISTRICT.

The eastern half of the Grants Pass quadrangle, which lies just west of the Medford district, is in Jackson County and the western half in Josephine County. Grants Pass, the county seat of Josephine County, is the most important mining center in southwest Oregon and is the distributing point for a large district to the south and west.

The location of the principal mines and prospects is shown on the accompanying map (Pl. V). For the description of most of them I am indebted to Prof. Kay.

BRADEN MINE.

The Braden mine is in the SE. ¼ sec. 27, T. 36 S., R. 3 W., about 3 miles from Gold Hill. It is owned by C. R. Ray, of Tolo, but in 1907 was leased to the Opp Mining Co., which continues operation.

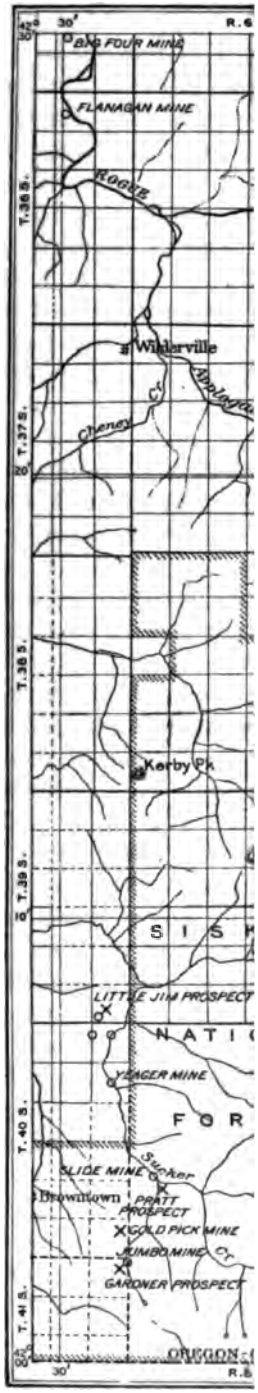
E. W. Liljegran, mines manager for Mr. Ray, has given the following information with regard to this property:

This mine was located about 25 years ago by B. A. Knott, of Gold Hill. He began development, the ores being treated in an arrastre. The ownership of the mine passed in succession to several persons, one of them being Dr. James Braden, after whom the mine is named. He sold to Mr. Ray in 1900. The greatest production of this mine for any one year was in 1907, when the value of the output was more than $30,000.

The equipment of the mine consists of a 10-stamp mill, one giant crusher, four Johnston concentrating tables, one air compressor, and machine drills. The plant is equipped with electric power, brought from Tolo, on Rogue River, a distance of about 5 miles. The property has been developed mainly by drifts along the vein and by winzes and upraises from these drifts. The vein outcrops along the southeastern slope of a hill and dips southeastward. The angle of dip of the vein is greater than the angle of slope of the hill; hence the lower drifts on the vein are at greater depths below the surface than those higher up on the vein. There are four main drifts, one above another. The aggregate length of these drifts is nearly 3,000 feet, and the greatest depth below the surface—less than 250 feet—is in a winze from the lowest of these drifts. The longest drift is the lowest on the vein. It is more than 1,200 feet long and considerable high-grade ore has been taken from the winzes and upraises made from it.

The rocks in which the ores are found are fine grained and of a dark-gray color; in hand specimens small crystals of feldspar may be seen. Under the microscope the rock appears distinctly porphyritic, the groundmass being microcrystalline. The phenocrysts are mainly plagioclase feldspar, but a few crystals of hornblende, probably secondary from augite, are also present. This rock is related to the greenstones, a large area of which lies in a northeast-southwest direction in this part of Jackson County. The area widens greatly in a short distance to the south. The main part of this large area of greenstone is thought to be composed of volcanic rocks interbedded with Paleozoic sediments. The evidence in favor of these rocks being volcanic consists of the presence in many places of amygdaloidal and tuff-like characters. Where such characters are absent it is difficult to distinguish those greenstones which are of volcanic origin from those which are fine-grained intrusives.

The vein in which the ores are found strikes about N. 30° E. The average width of the vein is not more than 2 feet. In places it pinches out entirely, and in other places, instead of one distinct vein with definite walls, there is a brecciated zone, which varies from a few feet to more than 15 feet in width. Within this zone the aggregate


BIG FOUR MINE
FLANAGAN MINE
Rogue
T. 36 S.
Wilderville
Applegate
Cheney Cr.
T. 37 S.
T. 38 S.
Kerby Pk.
T. 39 S.
S I S K
LITTLE JIM PROSPECT
N A T I
YEAGER MINE
F O R
T. 40 S.
SLIDE MINE
Sucker
Browntown
PRATT PROSPECT
GOLD PICK MINE
JUMBO MINE
Cr.
GARDNER PROSPECT
T. 41 S.
OREGON
30'
R. 8

MAP SHOWING

width of the quartz veinlets does not exceed 3 feet. In general the dip of the vein is about 25° SE., but in some places it is nearly flat and in others the angle of dip is high. There are several faults, but they are of small throw—generally from 1 foot to 3 feet, exceptionally as much as 20 feet. These faults are approximately parallel to one another.

The vein filling consists chiefly of quartz and sulphides; a very subordinate amount of calcite is present. The most abundant sulphide is pyrite, but arsenopyrite, chalcopyrite, and galena occur in small quantities. The best ore is found in those parts of the vein which are richest in sulphides; where the quartz is comparatively free from sulphides the gold content is low.

During 1907 the average yield of concentrates was 1 ton from every 12.2 tons of crude ore, these concentrates having an average value of $26 a ton. The average gold and silver content of more than 3,700 tons of ore treated in 1907 was worth about $9 a ton; the silver content was worth only about 22 cents a ton. About 65 per cent of the gold and silver of the ores was saved by amalgamation and about 25 per cent by concentration; the remaining quantity was lost in the tailings. The concentrates were shipped to Selby and to Tacoma.

Most of the production of the mine has come from two shoots, nearly 600 feet apart, on the lowest drift of the mine. One of the shoots extended along the vein in this drift for about 55 feet, but in a winze its width increased to about 80 feet, below which it narrowed abruptly. The direction of the shoot was the same as that of the dip of the vein. The other shoot had a length along the strike of the vein of 75 feet; in a winze from it the length increased to 125 feet; at the bottom of the winze, which was run 200 feet below the drift, the ore was low in grade. The direction of this shoot was about S. 50° E. Usually the best ore was found along the footwall of this shoot, although in places the gold and silver were uniformly distributed across the vein, which here had an average width of about 18 inches.

The zone of oxidation does not extend farther than about 100 feet below the surface, and in parts of the vein sulphide ores are found at depths considerably less. Along the fault planes the ores show enrichment.

OPP MINE.

The Opp mine, a short distance southwest of Jacksonville, is one of the important producing mines in southwest Oregon. It is an old mine reopened within the last few years but was not examined by Prof. Kay when he was in that region. It is reported in 1912 as operating a crusher and a 20-stamp mill, with equipment for amalgamation, concentration, and cyanidation.

GRANITE HILL MINE.

The Granite Hill mine is in sec. 29, T. 35 S., R. 5 W., near the north boundary of the Grants Pass quadrangle. A good wagon road runs from Grants Pass to the mine, a distance of about 9 miles. In July, 1908, this mine had been closed for several months and all the workings were filled with water. From Mr. C. M. Morphy, the former superintendent, many of the following facts were obtained. The mine is now owned by the American Goldfields Co., which also owns the property in the vicinity, including the Red Jacket and Ida mines, on which several hundred feet of development work has been done. The present owner obtained the Granite Hill property in 1901, and almost all the development work has been done since that time. During the years 1904 to 1907 the value of the production was more than $65,000, the largest output having been in 1905.

The mine is equipped with a 20-stamp mill, which has a capacity of 90 tons a day, a crusher, concentrating tables, engines, compressors, hoists, machine drills, and a Worthington mine pump. Electric power was used. When the mine was in operation as many as 50 men were employed.

The mine was developed by workings which aggregate nearly 3,000 feet. A vertical shaft of 420 feet intersects the vein at a depth of about 120 feet. From depths of 200, 300, and 400 feet on the shaft crosscuts were run to the vein and drifts made along the vein. The profitable ore between the levels was stoped out and raised through the shaft to the surface.

The country rocks are related to the granodiorites, a narrow tongue of which extends southward into the Grants Pass quadrangle from a larger area of these rocks in the Riddles quadrangle. To the east of the granodiorites is greenstone, to the west serpentine. At the Granite Hill mine gold has been found only in the granodiorite, but at the Red Jacket and Ida mines it occurs in the greenstone.

The vein runs in an east-west direction and has an average width of about 5 feet. In places the vein is brecciated, the fractured zone having a maximum width of about 20 feet. The dip of the vein is about 70° S. The vein filling consists of quartz, pyrite, chalcopyrite, and galena, carrying gold. The sulphides comprise about one-half of 1 per cent of the ores, and as concentrates they yield about $75 to the ton. The average gold value of all the ores treated in 1907 was about $5 a ton.

Mr. Morphy stated that the richest ores were found in shoots, of which there were three, each having a length along the vein of about 150 feet and a dip west of south.

The zone of oxidation extends to a depth of more than 200 feet from the surface, and the oxidized ores were the richest in gold.

MOUNTAIN LION MINE.

The Mountain Lion mine is in the western part of sec. 25, T. 37 S., R. 5 W. It was discovered in 1889 by the Messrs. Bailey, who, with Messrs. Davidson, Jewell, and Harmon, are the present owners. No work has been done on the property for several months. The equipment consists of a 5-stamp mill, concentrating tables, compressor, and engines. When the mine was in operation before 1908 as many as 25 men were employed.

The property has been extensively developed, there being about 8,000 feet of crosscuts, drifts, and other workings. Work has been done on two veins, which are in greenstone and slates and which are close to the contact of these rocks with an area of granodiorite. The slates occur as narrow lenses in the greenstones, and the best ore of the veins has been obtained near the contacts of the greenstones and the slates. The better-defined vein of the two strikes N. 80° W. and dips 65° S. It averages about 1 foot in width and is faulted at many places. The vein filling consists chiefly of quartz, calcite, and sulphides, the sulphides constituting about 1 per cent of the whole. Owing to the prevalence of faults the vein has been difficult to follow. In 1912 the Mountain Lion was reported in operation.

TIN PAN MINE.

The Tin Pan mine is in the SE. ¼ sec. 31, T. 36 S., R. 3 W., on the divide between Galls Creek and Foots Creek. The property was located many years ago. It is now owned by the Pacific American Gold Mining Co. T. T. Barnard was superintendent during the summer of 1908.

The mine is equipped with a 10-stamp mill, a Blake crusher, and two concentrating tables. No large body of profitable ore has been found, although more than 1,200 feet of drifts, shafts, and other workings have been made on the vein.

The country rocks in which the ores occur are slates, limestones, and greenstones, the greenstones apparently being intrusive in the sedimentary rocks, although some of them may be volcanic. The sedimentary rocks strike about N. 13° E. The strike of the vein is between northeast and east and the dip is nearly vertical. The vein ranges in width from less than 18 inches to more than 6 feet of solid quartz between definite walls, which are in general but slightly altered. In places there is a gouge from 1 to 3 inches in width. This material is claylike, but it contains carbonates and sulphides. Most of the gold content of the vein is in the sulphides, which run about $60 to the ton. The sulphides are pyrite and galena, which together constitute less than 2 per cent of the ores. Some faulting has occurred.

The zone of oxidation reaches a depth of more than 100 feet.

STAR MINE.

The Star mine is in sec. 6, T. 39 S., R. 4 W., west of Thompson Creek and about 4 miles from Applegate post office. This property was located in 1896 by J. J. Kunutzen. Very little development work was done until 1904, when E. B. Hawkins and Harry N. Morse became the owners. They spent about $20,000 in development. Thus far only about 800 tons of ore has been milled. The gold content was low, running only from $2 to $4 a ton.

The ore was quarried from an area of fine-grained greenstone in which numerous small stringers of gold quartz run in various directions. No distinct vein was found.

MAID OF THE MIST MINE.

The Maid of the Mist mine is in sec. 4, T. 39 S., R. 4 W. It is owned by William Wright, who did considerable work on the property during 1906 but suspended operations in May, 1907. During the summer of 1908 it was bonded by the South Oregon Mines Co., and preparations were being made to conduct extensive developments. More than 500 feet of work, mainly in shafts and drifts, had already been done, and compressors and hoists were being installed.

The country rock is greenstone. The gold-bearing quartz occurs in veinlets, which run in various directions. One of the most persistent of these strikes N. 85° W. and dips 55° S. The gold is irregularly distributed through the quartz, which is fairly free from sulphides. Of the sulphides, arsenopyrite appears to be more prevalent than pyrite. Calcite is subordinate.

JEWETT MINE.

The Jewett mine is close to the boundary between secs. 27 and 34, T. 36 S., R. 5 W., about 4 miles from Grants Pass. It was discovered about 1880 by Thomas Jewett. It now belongs to the estate of Benjamin Healy, of San Francisco. During the summer of 1908 no work was being done, but J. T. Hoare, the superintendent, stated that development was soon to be resumed. A short distance from the mine is a 5-stamp mill. There are seven claims, on which more than 1,500 feet of work has been done.

The country rocks are intrusive greenstones closely related to gabbro. Near the workings a dike of granodiorite cutting the gabbro was observed. The ores do not occur in a vein with definite walls but in small stringers in a brecciated zone, which is irregular both in direction and in width. The most pronounced direction is about N. 20° W. In places the width of the zone of brecciation is more than 20 feet. The filling between the fragments of the breccia consists chiefly of quartz and calcite, the latter being subordinate. Irregularly distributed through the quartz is a small amount of

pyrite, pyrrhotite, and a glistening steel-gray mineral which, when boiled with concentrated sulphuric acid, gives the purplish-colored reaction characteristic of a telluride. The properties of the mineral correspond to those of sylvanite. It was found without difficulty in several tons of ore on the dump.

OREGON STRONG LEDGE.

Among the producing mines of the Grants Pass region in 1908 was the Oregon Strong Ledge, reported from the vicinity of Murphy. At the time of my visit in that region the mine was not in operation, and it has not been examined.

OTHER MINES AND PROSPECTS.

Several other mines and prospects might be described, but they would present no new features. Among such may be mentioned the Bill Nye mine, which was closed for several years but recently started up again, also the Sylvanite and Gray Eagle, on Sardine Creek, as well as the Michigan mine, near Murphy. Though for a number of years inactive, the Michigan mine, in charge of Adolph Maier, according to the Rogue River Courier, has recently erected a 24-ton mill in which a hydroelectric chlorination process is employed. In 1912 the Michigan mine, together with the Norling mine, which has a 5-stamp mill, and the Buzzard mine, which has a 3-stamp mill, were reported in operation. Other properties which should be mentioned are the Lawrence mine, McMurtry mine, Alice group, Gold Pick mine, Gardner prospect, Pratt prospect, Millionaire mine, Oregon Bonanza mine, Oregon Belle mine, and Owl Hollow prospect. On the first seven of these no work has been done for some time; on each of the others a small amount of development is being done.

Chief among the "pockets" of ore that have been found within the area are the Gold Hill, the Roaring Gimlet, the Revenue, the Steamboat, and the Harrison. The locations of these are shown on the map. For the following account of the famous Gold Hill and Roaring Gimlet pockets I am indebted to Mr. E. W. Liljegran, of Medford, Oreg.

The most famous pocket so far discovered is the one from which the town of Gold Hill takes its name. It was discovered in 1857 on top of the mountain about 2 miles east from the town of Gold Hill.

The outcropping rock was so full of gold that it could scarcely be broken by sledging. The crystallized quartz associated with the gold was not honeycombed, as it generally is where sulphides have leached out of the rock, leaving sprays of gold in the cavity. The gold in this pocket went down only 15 feet and occurred in a fissure vein, strike about S. 20° E., dip about 80° E., with a gash vein cutting the fissure nearly due east and west and dipping vertically.

The fissure vein averages fully 5 feet between walls, with 1 to 2 feet of gouge on the footwall, which contains some calcite and quartz mixed with a little sulphide of iron, in spots containing free gold. A mass of micaless granite, about 5 feet wide by possibly 200 feet long, outcrops in the footwall side of the fissure. The country rock is pyroxenite. It is said that this pocket produced at least $700,000. There were a number of smaller finds in this immediate vicinity, none over 300 feet from the large deposit.

The Roaring Gimlet pocket, discovered in 1893, is situated at the mouth of China Gulch, about 2½ miles due south of the Gold Hill pocket. The Gimlet pocket gold was apparently liberated from oxidized sulphides, with very little quartz; the surface showed a porphyry dike 2 feet thick on the footwall and a slate hanging wall. The soft gouge, from one-fourth of an inch to 6 inches thick, between the slate and the porphyry, contained gold. The strike of the vein was east and west; dip 80° N. This vein contained a number of pockets, three between the surface and a depth of 40 feet, where the gouge continued down between solid dioritic walls, with a sprinkling of iron sulphides in small kidneys of calcite and quartz, looking very much like the vein filling in the Gold Hill vein. Several small pockets were extracted just east of the large Gimlet pocket, all within 300 feet of the first. Their combined production is said to have equaled $40,000.

GALICE-KERBY-WALDO REGION.

GENERAL FEATURES.

The most important mines and prospects of the Galice-Kerby-Waldo region in 1911 are shown on the map (Pl. VI). Of the 119 mines and prospects noted 52 are placer mines and 67 are lode mines and prospects. Among the lode mines and prospects 58 are for gold, 8 for copper, and 1 for both gold and copper. All the placer mines are productive, but of the lode mines only 2 are accredited with a production of gold and copper and 20 with a production of gold alone.

The chief mineral resources of the area under consideration, which lies almost wholly in Josephine County and forms about one-fourth of its area, are gold, copper, silver, and platinum, and these metals are obtained from both lode and placer deposits. The production of copper ceased in 1910, but began again in 1911 and increased decidedly in 1912, by the Almeda Consolidated at Galice and the Elder Mining and Smelting Co. at Takilma.

The total gold production in Oregon during the last 13 years amounted to $15,663,258. Of this approximately $5,749,976 came from southwest Oregon, $3,434,915 being from the placers and $2,315,061 from lode mines. Of the total amount of gold produced

V
n
a
fc
p
ti

li
o
an
of
ci
M

ar
fr
$2

in Josephine County, as shown in the following table ($3,682,055), approximately $1,905,258 came from placers and $1,776,797 from lodes.

Comparative value of the annual production of gold in Josephine County and the entire State of Oregon from 1900 to 1912.[a]

Year.	Josephine County.			Oregon.
	Total.	Lode.	Placer.	
1900	[b] $449,397	[b] $210,463	[b] $238,934	$1,694,700
1901	[b] 482,973	[b] 225,873	[b] 257,100	1,818,100
1902	[b] 481,748	[b] 225,299	[b] 256,449	1,816,700
1903	342,133	160,006	182,127	1,290,200
1904	[c] 373,670	[c] 229,608	[c] 144,062	1,412,186
1905	[c] 401,986	[c] 280,596	[c] 121,390	1,405,235
1906	362,289	233,128	129,161	1,366,900
1907	160,668	39,405	121,263	1,129,261
1908	152,722	36,134	116,588	865,076
1909	148,997	42,364	106,633	781,964
1910	150,048	63,273	86,775	679,488
1911	99,363	12,806	86,557	633,407
1912	76,061	17,842	58,219	770,041
Total	3,682,055	1,776,797	1,905,258	15,663,258

[a] Compiled chiefly from statistics by Charles G. Yale in U. S. Geol. Survey Mineral Resources for the years 1906 to 1912.
[b] Estimated from the annual production of Oregon on the proportional production of 1903.
[c] Includes production of Lane County also.

Gold is said to have been discovered in this region on Josephine Creek on May 2, 1852.[1] Placer mining began with a rush and has continued more or less vigorously ever since, but the annual production was greatest in the last century, when the richest placers were worked. It seems, therefore, well within the bounds of probability to regard the average annual production of gold in Josephine County from 1852 to 1900 as not less than $450,000, for during the first three years of this century the average must have been somewhat greater than that amount, although there has since been a decline, owing especially to the decline of the placers. On that basis, which although generous seems reasonable, Josephine County has produced only about $25,000,000 in gold. The claims sometimes made that a small portion of the district has produced many millions are highly improbable. A fair estimate credits the Galice-Kerby region with a production of $10,000,000 in gold alone. In general the Galice and Kerby districts have been about equally productive. This might be expected from the fact that the same rock belts and other geologic features, as shown on the map (Pl. VI), traverse both districts. The productive portion of the Galice-Kerby region is a belt about a dozen miles in width, made up chiefly of igneous rocks—serpentines and greenstones. This belt includes patches of Mesozoic slates and is bounded both on the northwest and southeast by slates of essentially the same character.

[1] Pamphlet on mining in Josephine County, published by Grants Pass Chamber of Commerce, 1911.

A distinct but small belt of unimportant production includes lode prospects and placer mines in the neighborhood of Mount Bolivar, near the northwest corner of the area mapped (Pl. VI). This belt lies about 15 miles northwest of the Galice-Kerby belt, and the two belts are in a measure united by the placers of the two transverse master streams, Rogue and Illinois rivers. Both belts contain prospects or mines of gold and copper.

ORIOLE MINE (32).[1]

The Oriole mine is situated in Rocky Gulch, 2 miles by wagon road northwest of Galice, at an altitude of about 1,200 feet above sea level and 400 feet above Galice on Rogue River. It is 19 miles from the Southern Pacific Railroad at Merlin and may be readily reached by stage.

The Oriole Gold Mining Co. was organized and began work in 1909. The company owns nine claims, in places four in width and three in length, which lie along the lode with some variation nearly north and south. The mine, which was developed under F. A. Jones, mining engineer, has four levels. The main adit tunnel of 890 feet taps the lode over 500 feet beneath its outcrop. More than 3,200 feet of underground workings on the four levels open the lode through a depth of 340 feet and a length of 1,085 feet.

A 50-horsepower water head and dynamo is to light the mine and plant, which includes a well-equipped laboratory. Near the site of the hydroelectric plant a combination mill will be erected according to the plans of Mr. Jones. The dam and headrace are partly completed.

The Oriole lies on a well-marked fault along the contact of quartz porphyry and greenstone. The course of the fault in the mine is N. 5° E. and the dip is 76° SE. beneath the quartz porphyry of the hanging wall. The evidence of displacement is clear from the presence of a conspicuous gouge and the polished striated surface of the hanging wall of quartz porphyry, but the amount of the displacement could not be determined. The gouge, which is generally 6 to 8 inches thick, is a greenish to bluish gray clay, and few of the striations on the fault plane are vertical. They are generally inclined but not uncommonly are horizontal, showing very distinct movements at different times. The greenish-gray gouge is composed largely of ground-up greenstone, which crushes and shears more easily than the quartz porphyry.

For many feet from the contact the greenstone is greatly sheared and contains irregular lenses or veins of quartz, as shown in the section of the contact (fig. 7).

The levels are run in the greenstone and have numerous crosscuts only 10 to 25 feet in length to the contact. A few crosscuts are run

[1] Numbers refer to location on the map (Pl. VI, p. 46).

in the opposite direction 50 to 210 feet into the greenstone. The greenstone in the shear zone is highly chloritic. In fact, the veins or lenses of quartz are completely incased in a deep-green chloritic mineral of which Mr. Jones has made the following analysis:

Analysis of chloritic minerals from the Oriole mine, near Galice, Oreg.

SiO_2	37.70
FeO	13.54
Al_2O_3	18.16
CaO	3.00
MgO	17.21
H_2O	10.32
	99.93

This analysis shows the material to be a mixture of chloritic minerals or possibly related to clinochlore. The high percentage of silica may be due to included quartz, to which the chloritic minerals adhere. It is the gangue, so to speak, of the quartz nodules and contains cubes of pyrite.

The quartz is milk-white to grayish white in color and forms irregular rough-surfaced bodies which range in shape from a mere filmy vein to lenticular bunches several feet in diameter with their greatest dimensions in the plane of schistosity and parallel to the contact, as shown in figure 7. The quartz bodies generally contain a few irregular filmy patches of chlorite besides the scattered particles of ore minerals and are traversed at various angles by slickensided surfaces on which there has evidently been movement since the deposition of the quartz.

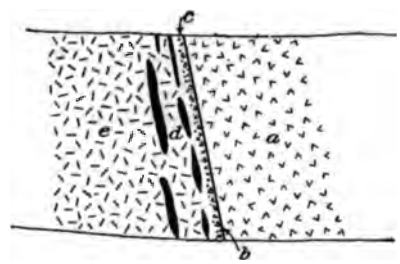


FIGURE 7.—Section of contact in Oriole mine. *a*, Quartz porphyry; *b*, fault plane, polished quartz porphyry; *c*, greenish to bluish-gray gouge, 6 to 8 inches thick; *d*, ore zone of quartz lenses in sheared greenstone 3 to 10 feet in width; *e*, sheared greenstone.

The ore minerals are apparently pyrite and chalcopyrite in small, sparsely scattered particles or crystals in the quartz, but are more abundant as irregular crystalline scales on the fracture planes and fault planes which traverse the quartz. Some of the scales are polished, showing that fault movements continued after the deposition of some if not all of the ore. Some lenses of milky quartz occur without visible trace of ore, whereas in others, generally of gray quartz, the ore appears to form as much as 5 per cent of the quartz body. Portions of the pyrite and chalcopyrite are strongly tarnished, giving iridescent purplish to black colors. Possibly, however, the

black dustlike particles are of a third mineral, perhaps a telluride, which it is claimed assayers have reported in the Oriole ore. The pyrite crystals are cubical and generally have a decidedly gold-yellow color suggesting, to the miner at least, the presence of gold.

F. A. Jones, the engineer of the Oriole, assayed the ore and regarded it as probably a sulphotelluride of gold, silver, copper, and iron, for which he suggested the name oriolite, after the name of the mine in which it occurs. A typical sample of the ore was selected for the purpose of mineralogic determination. It was submitted to qualitative test in the Geological Survey laboratory by W. T. Schaller, who reports that "the concentrated sulphides contain much iron, a small amount of copper, and doubtful traces of tellurium and gold. Neither tellurium or gold is present in appreciable amounts and the sulphides of the ore consist essentially of pyrite and chalcopyrite."

I was informed at the mine that the workable ore ranges in value from $4 to $200 a ton, the average being from $15 to $20 a ton. To judge from the aspect of the ore in sight, the average value would not appear to be so high and the average value on level 4 would be somewhat less than that on the higher levels. On the higher levels the ore lies near the contact and is so distributed as to suggest shoots which have not yet been found in the lower level. It is proposed to erect a combination stamp mill for treating the ore after concentration, but actual construction of the mill has not yet begun, although the Oriole Gold Mining Co. has recently bought and moved to its own property the old stamp mill of the Sugar Pine mine.

RICHMOND GROUP.

The Richmond group, north of the Oriole, embraces 12 claims in the head of Rocky Gulch and laps over into the head of Deer Lick, a branch of Bailey Creek. Seven tunnels, aggregating 600 feet or more, have been run in various directions into the sheared greenstone, exposing some quartz kidneys and veins with but little visible ore. Most of the gold was found with quartz near the summit on both sides of the divide. A ball mill and an old arrastre, both in ruins, were once in operation, but their output I was unable to learn. The Oriole fault and lode enter the Richmond group, but farther north, near the divide, are not so well marked, though quartz veins are more numerous, some striking west of north toward the Golden Wedge, whereas others run east of north toward the Arago. The only work in progress in July, 1911, was on the Deer Lick slope, where an 18-inch rusty quartz vein appears, which is said to assay $15 to $20 a ton.

GOLDEN WEDGE MINE (20).

The Golden Wedge, 4 miles northwest of Galice, was discovered by Mr. Hutchins in 1893. Later the company became the Golden Road and reorganized as the Bailey Gulch Mining & Milling Co. The property embraces about half a dozen claims.

The total production of this mine operated by the two companies mentioned above may have been as much as $50,000, and if an ore body is found, as the present management expects, in the deep tunnel where it cuts the Oriole fault, the mine may again become an active producer.

Nearly 1,200 feet of underground workings in greenstone exploit the deposit for about 500 feet in length and to an equal extent in depth. The plant consists of a 14-stamp mill with numerous vats for cyaniding the ore and is reported to run on an average about four months a year. The ore belt strikes nearly north and south and dips 38°–70° E. The quartz veins and lenses in the sheared greenstone are irregular as if folded, and many of the quartz lenses or kidneys that have a covering of graphitic material with grains of pyrite are said to average $10 to $20 a ton in gold. Considerable ore has been stoped out of a belt ranging from 16 inches to 5 feet. The graphitic material interferes with milling the ore. The country rock is greenstone, but varies widely.

In an old tunnel near the mill on Bailey Creek a fault appears which contains grayish-blue gouge between the hanging wall and quartz lenses in sheared greenstone like that of the Oriole. Though it lies a short distance west of the line of the Oriole fault, most likely it belongs to the same movement. The tunnel being driven in 1911 was already in about 500 feet and was expected to reach the line of the fault in a short distance.

ARAGO GROUP (22).

The Arago group, embracing seven claims, lies northeast of the Richmond and reaches Rogue River 2 miles below Almeda. Three tunnels, aggregating about 300 feet, run in on the veins near the river. The plant consists of a small unused ball mill. Schistose greenstone is the country rock. The irregular quartz veins, stringers, and kidneys occur in a belt about 3½ feet wide. They strike N. 28°–35° E. and are generally vertical, but in some places dip 76° NW. The quartz contains but little pyrite, though in places it yields a small amount of gold. The only deposit yet found is said to have been worked out years ago in the bed of the river.

SEVEN-THIRTY MINE (21).

A short distance northwest of the Arago is the old Seven-Thirty mine, now closed but reported to have been at one time productive.

Quartz prospected in that region recently has panned a small amount of free gold.

KRAMER PROSPECT (25).

The Kramer prospect is situated at the head of the west branch of Rocky Gulch, about a mile northwest of the Richmond, at an altitude of nearly 3,000 feet. There are numerous prospect holes and tunnels and an old arrastre and cabin. It is said that in the winter of 1909–10 ore was packed over to the mill at the Golden Wedge to be worked.

The country rock is a banded quartzite containing numerous scales of mica and grains of pyrite changed to limonite that give color to the rock and soil.

There was no one at the mine, no bodies of ore were seen, and I was unable to obtain satisfactory samples.

ELWILDA (HUBBERT) MINE (10).

The Elwilda group of 11 claims extends from Rogue River up Whisky Creek. About 250 feet of tunnels open the property at three levels. The old four-stamp combination mill is being replaced by a Lane type of wheel arrastre. There are two points of work—the upper near Whisky Creek and the other, a mile farther southwest, nearer Rogue River. In both places the country rock is greenstone and serpentine, and the deposits prospected lie in the greenstone not far from the contact.

The quartz vein of the upper tunnel strikes N. 5° E. and dips 68° NW. It has a thickness of 3½ feet for a short distance where worked out. The gold in the vein is reported to average about $5 a ton. When tested by panning a small amount of free gold and pyrite was observed. Some chalcopyrite was seen at the lower opening, where the ore was obtained some years ago for the old mill. Mr. J. C. Hubbert, the manager of the property, informed me that 300 tons from this mine shipped to Selby & Co. yielded a good profit.

The lower openings in the greenstone are nearly 300 feet from the contact with the serpentine and expose a fault that strikes N. 85° E. and dips 52° SW. The principal quartz vein in these openings is 3 feet thick and is much crushed and faulted. The strike of the vein is nearly east and west across the belt of greenstone toward the contact with the serpentine. The crushing indicates that the faults are due to compression. The contact at this point runs S. 40° W. across Rogue River toward the Keystone mine.

GOLD BUG (13) AND MINES OF MOUNT REUBEN.

The serpentine cutting the greenstone at the mouth of Whisky Creek extends northeast and probably has had an influence in the mineralization of the mines about Mount Reuben, the Gold Bug (13),

the Benton (11), and the Copper Stain (12). The Looney (14) and Devortney (15) claims, farther northwest, are nearer the contact of the greenstone and slate. While in the Whisky Creek region I learned that little or no development work was going on at that time on any of the mines about its head. A large amount of development work has been done in that region and several mills have been erected. A few years ago the Gold Bug was an active producer. The Benton and the Gold Bug are connected directly by wagon road with the Southern Pacific Railroad at Reuben Spur.

MOUNT BOLIVAR REGION.

The mineralized belt of greenstone in the Mount Bolivar region is impregnated at many places by pyrite, chalcopyrite and bornite, and contains many veins of quartz and calcite. It is best developed about Saddle Mountain and Mount Bolivar and extends from Rogue River northeast along John Mule Creek across the west fork of Cow Creek and disappears beneath the covering of Eocene rocks.

Many prospects have been opened in this belt, especially about the two peaks mentioned. The most important prospect, locally known as the Thompson mine, has been exploited by several tunnels and inclines which yielded approximately 50 tons of copper ore, chiefly chalcopyrite and bornite. The works were closed at the time of my examination, but the occurrence of so much ore on the dumps apparently shows the existence of ore bodies of considerable size.

KEYSTONE GROUP (19).

The Akron Gold Mining & Milling Co. owns 5 claims on the south slope of Rogue River canyon nearly opposite the mouth of Whisky Creek. It is reached by trail and is only about 12 miles from Galice. There are two openings far above the river. One of them, 115 feet in length, cuts the ledge at a depth of 100 feet; the other, 160 feet lower, is only partly completed.

The country rock is greenstone near its contact with intruded serpentine and the general relations of the prospect are the same as those of the Hubbert mine, about 1½ miles northeast, across the river on Whisky Creek.

The gold occurs in irregular quartz veins or stringers, forming a belt about 3 feet in thickness and approximately parallel to the serpentine contact.

The ore appears to be pyrite in fine particles sparsely disseminated through the quartz. It is oxidized near the surface, where the quartz is porous and striated by limonite. No assays are available to show its value.

A number of other claims have been located near the same belt of serpentine farther south, the Norbourg (24), the Shirt (25), and the Treasury group (26)—all in greenstone—on the west, and the Legal Tender (20) and the Buffalo (36) in banded quartzite on the east.

LEGAL TENDER GROUP (20).

The Legal Tender group embraces three claims located on the east fork of Rum Creek at an elevation of 2,850 feet. A tunnel 100 feet long penetrates what appears to be rotten greenstone, but farther up the ridge the rock is seen to be more or less distinctly banded quartzite cut by serpentine. There are about 5 tons of ore at the mouth of the tunnel. It consists largely of decomposed ferruginous quartz with some pyrite unchanged and is reported to have assayed $12 per ton. The owner plans to erect a 5-stamp mill on the property.

TREASURY GROUP (26).

The Treasury group, embracing four claims, is located about 4½ miles northwest of Galice, at the head of the north fork of Galice Creek. At an elevation of about 3,500 feet a tunnel 150 feet in length reaches a fault with a small deposit of ore. The fault runs east and west and dips 45° S., beneath the hanging wall of greenstone which is clearly derived from pyroxenite, about one-third of which has changed to green hornblende. The ore body in bulk is at least 75 per cent quartz, with scattered grains of copper and zinc ore—chalcopyrite, pyrite, malachite, and sphalerite.

The upper openings near the crest of the ridge expose a 4 to 5 foot vein of quartz with scattered sulphide ores. This vein, however, runs north and south at right angles to the vein noted in the tunnel several hundred feet below. It is said that a short distance farther west prominent quartz veins run east and west as in the tunnel, but the development work is not sufficiently advanced to determine the relations of the veins. The character of the ores in the limited quantity seen is such as to suggest the necessity of concentration before working.

RED ELEPHANT CLAIMS (27).

The Red Elephant consists of two claims, at an elevation of 1,500 feet, on Howard Creek about 7 miles northwest of Galice Mountain trail. The claims are opened up near the creek level by four tunnels aggregating about 165 feet in length, on which active work is continued. The country rock is greenstone and dacite porphyry permeated by a multitude of small veins and veinlets of quartz running in all directions. Both rocks are well exposed in the bluff of Howard Creek above the cabin. Thus the rocks are highly silicified and at the same time both veins and country rock are richly impregnated with pyrite. The mineralization is such as to render it diffi-

cult to trace the boundary between the dacite porphyry and greenstone. In fact, the presence of the dacite porphyry, though suspected in the field, was demonstrated only by the microscopic examination of the sections after returning to the office. The dacite porphyries cut the greenstones and the serpentines, and in all probability come from the source of the mineralizing agents of the region.

The mineralized belt is several hundred feet wide, and if the pyrite contains considerable gold it might be well worth concentrating for shipment or treatment on the ground. A sample, assayed for the Survey by E. E. Burlingame & Co., of Denver, Colo., yielded 0.023 ounce of gold to the ton.

Near the southeast side of the impregnated belt a 6-foot vein of gray quartz runs N. 35° E. The quartz contains a small amount of pyrite. It is said to have assayed $119 a ton in platinum and 15 per cent in tin, but there is no visible evidence in the hand specimen of the presence of such rich ore.

BLUE BELL PROSPECT (28).

The Blue Bell prospect is situated 6 miles northwest of Galice, on a branch of Howard Creek, a mile above the Red Elephant. It was opened up some years ago by nearly 200 feet of tunnels. A number of tons of ore were mined, but none of it was shipped. The ore is chiefly pyrite, like that of the Red Elephant, but contains also some chalcopyrite and dark bluish scales of molybdenite. This prospect was not examined, though the neighboring greenstone was seen on the hill to the northeast, where it is so rich in pyroxene as to be practically a pyroxenite. Some of the ore samples from this locality are much sheared and slickensided. The molybdenite appears to be the latest deposit on the shearing planes but before the final movements.

BUFFALO GROUP (36).

The Buffalo group of 14 claims on Peavine Mountain (elevation, 4,000 feet) is situated at the head of Quartz Creek, along the eastern side of the serpentine belt. Open cuts, short tunnels, or shaft prospects have been made on most of the claims, but only two deserve notice.

One of these claims is near the eastern side of the serpentine belt, where the abandoned quartzite is more or less richly impregnated with pyrite that is said by Mr. Wayment, the owner, to be auriferous. It is exposed at intervals for a mile by open cuts, shallow shafts, and tunnels. The dissemination of pyrite is rather sparse and no bodies of ore were seen. The belt of quartzite is approximately 300 feet in width, and the pyrite is most abundant near the serpentine contact. East of the quartzite is greenstone.

The second prospect to be noticed in the Buffalo group is on the Dixie claim in the greenstone. It lies at the head of Rocky Gulch, some miles above the Mayflower mill (37). A tunnel has been run in 279 feet, exposing several kidneys and irregular veins of quartz that contain some pyrite and chalcopyrite. The veins and kidneys run N. 23° E. and dip 68° NW., parallel to the slickensided wall showing faulting. About 2 tons of ore, pyrite, and chalcopyrite, have been taken out of the tunnel. The ore forms small irregular bodies in the sheared greenstone. No ore bodies were seen in the tunnel.

MAYFLOWER PROPERTY (37).

The Mayflower property is situated on the south fork of Rocky Gulch at an elevation of 2,810 feet, about 3½ miles northwest of Galice, near the main Peavine Mountain trail. It embraces three claims taken up in 1910. The rocks are well exposed on the steep slopes of the canyon that cuts across the contact between the greenstone and serpentine. The serpentine contains small remnants of the olivine and pyroxene of which the peridotite was originally composed.

The two small prospect tunnels are in greenstone near the contact. The gold is free or is in the pyrite, and chiefly, if not wholly, in the rotten quartz of the greenstone schist adjoining the contact. There is little if any gold in the white quartz. A small amount of chalcopyrite is present.

Some distance west of the serpentine contact and beyond the more siliceous greenstone there is a dark graphitic-looking rock which in thin section is found to be a graphitic mica schist containing two kinds of mica, muscovite and biotite, with graphitic dust and numerous particles of pyrite. This rock appears to contain free gold and forms a north and south belt which appears to be related to the banded quartzites of the eastern slope of Peavine Mountain.

The quartz mill recently built at the Mayflower is of the Chilian wheel arrastre type, and is to be run by a small Pelton wheel. It promises to be effective not only in proving but in developing the property.

BLACK BEAR MINE (38).

The Black Bear mine, situated about 2½ miles northwest of Galice, on the south fork of Rocky Gulch, is owned by the Black Bear Mining & Milling Co. Several tunnels, one of which is about 1,000 feet in length, and a 30-foot shaft constitute the development work.

The country rock is greenstone near its contact with serpentine that is derived in part from pyroxenite. A vertical belt of quartz veinlets and kidneys 2½ feet in width runs nearly north and south approximately parallel to the contact. Other quartz veins, some of which carry pyrite, run nearly east and west at right angles to those mentioned above. The ore, which is rich in pyrite, with some chalco-

pyrite, is scattered rather irregularly in the vein belt. About 4 tons of ore has been obtained from the 30-foot tunnel, and its value as shown by assays is said to range from $4 to $27 a ton, chiefly in gold and a little copper. Some of the ore is cut by shearing plains, on which the slickensided ore shows decided movement since the ore was deposited.

SPOKANE PROPERTY (39).

The Spokane property is situated about 2½ miles northwest of Galice, near the head of Rich Gulch. It lies in greenstone near the southwest edge of the serpentine-pyroxenite belt which separates it from the Black Bear mine. A number of prospect holes and small tunnels give evidence of considerable work but of short duration. The small arrastre is in ruins and the cabins deserted.

BLACK HAWK PROPERTY (40).

The Black Hawk property lies on Quartz Creek, not far from the eastern contact of the Peavine serpentine belt. Development work only has been reported for the last year.

The Black Jack group is near the Black Hawk. Although neither of these mines was visited, I have learned from good authority at Galice that the ore of the Black Jack group is free milling and that between $6,000 and $7,000 in gold was won from a pocket by hand mortaring.

NESBIT GROUP (41).

The Nesbit group, embracing 3 claims, lies about 2 miles northwest of Galice, near the Peavine Mountain trail, at an elevation of about 1,750 feet. The country rock is chiefly rotten greenstone a short distance southwest of the serpentine belt. The slopes are gentle and the greenstone is covered by a deep capping of yellowish iron-stained residual material which in places yields free gold. Considerable gold has been won from this residual material by panning. The average of a number of assays is said to be $6.50 a ton, and it seems probable that it would pay well to hydraulic the whole slope. However, the available water is all controlled by the Old Channel Co. The claims lie only a short distance above the Old Channel diggings and may well have contributed to their richness. A short tunnel and incline have been run into the decomposed material, and a longer tunnel is in progress to tap it at a level about 100 feet lower.

THREE LODES GROUP (42).

The Three Lodes group includes a number of claims on Blanchard Gulch, about 2 miles by road directly west of Galice, at an elevation of about 1,500 feet. The country rock is greenstone and serpentine and the 30-foot tunnel follows a fault gouge near the contact. The presence of water and the slippery serpentine render tunneling some-

what difficult. The serpentine in places along the tunnel is impregnated with pyrite but not so richly as to form ore bodies.

Several local assayers reported tin from this mine and also from the near-by Golden Pheasant, but there is nothing in the character of the rock as seen in the field that would suggest the presence of tin. Under the guidance of the general manager, F. F. Johnson, five samples of the reported tin-bearing rock were collected for test. Mr. Chase Palmer tested them in the chemical laboratory of the Survey and reports on every sample "no tin found." These tests simply confirm the tests previously made by Profs. Parks and Swartly, of the Oregon State Bureau of Mines and Agricultural College at Corvallis.

A short distance west of the Three Lodes opening, at the falls of Blanchard Gulch above the road, a vertical 5-foot ledge, apparently of banded quartzite, strikes N. 10° E. Farther up the hill toward the Hidden Treasure the ledge is prospected and the ore is said to run from $6.90 to $8.20 a ton in gold. Other prospects have been made farther northeast on quartz veins running N. 22° E. in slaty greenstone. They contain a little chalcopyrite and scattered pyrite in chlorite.

GOLDEN PHEASANT GROUP (49).

The Golden Pheasant group lies about 1¾ miles directly west of Galice near the contact between the slates of the Galice formation and the greenstones. A number of tunnels have been run into the greenstone at several levels. In quartz veins and kidneys running N. 30° E., in the lower tunnel, a bluish-black foliated mineral occurs sparsely. Chemical tests prove it to be molybdenite. From a pile of chloritic schist containing films of calcite on the shearing planes samples of the reported tin ore were taken, but careful tests by Dr. Palmer in the chemical laboratory of the Survey failed to show any tin.

The slates of the Galice formation and the greenstones are particularly well exposed near their contact at the falls in Blanchard Creek. Except that the country rock is greenstone instead of quartz porphyry, the mine seems to be at the horizon of the Big Yank lode of the Almeda mine, but from outcrops in view in Blanchard Gulch there is no evidence of the existence of important ore bodies.

SUGAR PINE MINE (50).

One of the mines that has attracted considerable attention in the Galice region is the Sugar Pine, on the North Fork of Galice Creek, about 2½ miles in a direct line southwest of Galice. It was opened by Cassady & Draper in 1860 and worked by Daniel Green and his brother for some years up to 1881, when it was sold to the Sugar Pine Mining & Milling Co.

The mine has over 2,800 feet of underground workings, of which the principal entrance and level, 800 feet in length, is at an elevation of about 1,700 feet. The country rock is greenstone, composed chiefly of green hornblende. The mine is only about 1,200 feet west of the contact between the slates of the Galice formation with the greenstone and serpentine.

The sheared belt, 1 to 5 feet in width, with its ribbons, veins, and kidneys of quartz along a well-defined hanging wall, runs approximately north and south and dips steeply to the west. As in the Oriole, the bunches of quartz are incased in chlorite. The ore minerals, chalcopyrite, pyrite, and galena, carrying values in gold and silver, are scattered here and there through the quartz. The ore from a rich shoot mined out by the Green brothers yielded between $25,000 and $30,000 when treated in an arrastre. A 10-stamp mill with two concentrators was erected in 1908, but ran only several months before closing. The mill has since been sold and removed to the Oriole.

GOLD PLATE PROPERTY (51).

A short distance south of the Teddy, on the steep north slope of the West Fork of Galice Creek at an elevation of 1,500 feet, lies the Gold Plate prospect, recently located and prospected by a number of tunnels. The greenstone is greatly crushed and the cavities filled with quartz crystals similar to those commonly present in a region of pockets. The veins in places near the cabin appear to lie flat, but near by on both sides they are vertical and strike N. 25° E. There is some pyrite in the quartz, but no important ore bodies are in sight.

VICTOR MINE.

The Victor mine is about 7 miles from Galice on the West Fork of Galice Creek. When in the region in 1911 I was unable to visit it, but Mr. C. L. Barlow, of Galice, informs me that the owners struck a rich vein and took out about $2,500 in a month with a hand mortar. In 1912, 5 men were still at work and were averaging more than $4 to the man a day.

STRENUOUS TEDDY CLAIM (52).

The Strenuous Teddy claim is situated about 3½ miles southwest of Galice, on the West Fork of Galice Creek at an elevation of about 1,620 feet. Two belts of vertically banded siliceous rocks, probably quartzites, running N. 15° W., form prominent bluffs. Each belt is about 150 feet thick and the two belts are separated by 125 feet of intrusive greenstone similar to that which bounds the quartzite on both sides. Tunnels have been run into both belts of quartzite, and the sheared rock has been found impregnated by pyrite—richly for 2 feet and sparsely for 5 feet. Part of the dark rock so rich in pyrite

appears indistinctly micaceous. To test the auriferous character of the pyrite a specimen of this rock was assayed for the Geological Survey by E. E. Burlingame & Co., of Denver, Colo., and yielded a "trace" in gold, but no silver. Farther up the slope are quartz veins containing cavities lined with quartz crystals and free gold.

COLD SPRING COPPER MINE (53).

The Cold Spring copper mine lies on the southwest slope of the West Fork of the Galice Creek nearly opposite the Sugar Pine. It was lately examined in detail under option by the Almeda Co., and half a ton of ore shipped for test. Although I did not see the mine, Mr. Daniel Green informs me that large bodies of copper ore, chiefly chalcopyrite, is in sight. The ore is said to be of good grade, but it has no associated galena, as at Sugar Pine.

CARLTON GROUP (54).

The Carlton group, embracing 9 claims, lies on both sides of the South Fork of Galice Creek 3 miles southwest of Galice, at an elevation of nearly 1,400 feet. The country rock is slate and greenstone, and their contact corresponds to the position of the Great Yank lode, on which the Almeda mine is situated. Two tunnels, aggregating about 250 feet in length, run into the greenstone near the contact. The greenstone in places where sheared is richly impregnated with pyrite and some chalcopyrite. The rock is so richly pyritized that if auriferous it would afford a concentrating ore. An assay made for the Geological Survey by E. E. Burlingame & Co. yielded a trace of gold. Some ore bodies are reported on the hillside a short distance south of the tunnels referred to, but the tunnels have not yet reached them.

LOST FLAT MINE (55).

The Lost Flat mine is on Chieftain Gulch about 4 miles southwest of Galice. It was discovered in the latter part of the seventies and operated irregularly for four or five years with an arrastre. Its production, however, is said to have been less than that of the Sugar Pine. A small amount of ore was shipped, but for test only, and the mine was closed.

QUEEN GOLD & COPPER MINE (61).

The Queen Gold & Copper Mining & Smelting Co. owns a mine about 3½ miles northwest of Wonder. The 11 claims, whose greatest length is northeast and southwest, cross the divide between Water and Limpey creeks and cover a belt of greenstone lying between the slates of the Galice formation on the northwest and serpentine on the southeast. A small placer at the head of one of the forks of

Water Creek near the contact between the greenstone and the serpentine yielded $3,000 in gold some years ago and started prospecting to find its source. A number of tunnels and crosscuts aggregating over 800 feet of underground workings have been run in the greenstone. At the time of my visit I found no one at the mine and did not see all of the openings. An interesting breccia of greenstone, cemented by quartz and about 12 feet in thickness, is exposed by the tunnel on the Limpey Creek side of the divide and may be locally mineralized. Outcrops of this breccia were seen as far west as Slate Creek, 2 miles below the Buckeye mine.

BUCKEYE MINE (62).

The Buckeye mine is on the East Fork of Slate Creek at an elevation of about 2,800 feet. It lies between the Queen and the Ramsey mine, about 5 miles northwest of Wonder. The country rocks are greenstone, serpentine, and slates of the Galice formation. The mine is near the contact of these rocks, and the several tunnels, probably not over 100 feet in length, are in the igneous rocks.

The plant reached by the Slate Creek road includes a small mill and cabins. The only ore seen was at the cabins. It consisted of quartz from veins and kidneys in greenstone. The quartz contains grains and bunches of chalcopyrite, pyrite, and resinous particles which appear to be zinc ore. There may have been a small production from this mine, but the amount has not been learned.

The gold is all in the greenstone and is most abundant within 30 feet of the contact, where much of the greenstone is crushed and brecciated. The rotten iron-stained greenstone of the shaft when crushed in a mortar and panned yielded a number of colors of pyrite and gold but none of platinum. This rock was supposed to carry high values, and for this reason a sample was assayed by Burlingame & Co., of Denver, who report as follows: Gold, 0.01 ounce to the ton; silver, 0.00 ounce to the ton.

In the tunnel near by another sample was taken of rock which Mr. Ramsey states a local assayer reports to contain high values in platinum. Burlingame & Co. report from an assay of this material as follows: Gold, 0.01 ounce to the ton; silver, 0.00 ounce to the ton; platinum, none present.

RAMSEY MINE (63).

On the West Fork of Slate Creek, about 6 miles northwest of Wonder, there is a group of three claims owned by W. H. Ramsey. The claims cover greenstone and its contact with serpentine. The workings include two small tunnels about 40 feet in length and a 12-foot shaft at an elevation of about 2,800 feet.

The soil in the immediate vicinity of the contact of serpentine and greenstone has been sluiced off for nearly 100 feet and is said to have paid well in relatively coarse gold. In fact, all the dirt I tested thereabouts when panned yielded numerous colors of fine gold.

In the upper tunnel the fault contact of the serpentine overlying the greenstone is well exposed, striking N. 25° W. and dipping 62° NE. This is, however, in a bend of the contact, for the general trend of the contact of serpentine and greenstone is N. 30° E. and dip 40° SE.

Some distance west of the contact toward the creek another tunnel has been run into crushed greenstone, and the iron-stained rock has been reported by local assayers to contain a small percentage of tungsten.

A sample selected by Mr. Ramsey and myself to test this matter was sent to the laboratory of the Geological Survey, where it was tested by R. C. Wells and found to contain no tungsten but a small fraction of 1 per cent of vanadium.

Mr. Ramsey has a small water-power arrastre by his cabin on Slate Creek conveniently located with reference to the mine, with which it is connected by a trail. Road construction would be comparatively easy, but very little has yet been accomplished in either production or development.

A report on this mine by Adolph Maier, of Grants Pass, was published in the Courier of that city, June 25, 1911, giving much higher values for the ores than those noted above.

OLD GLORY PROPERTY (66).

The mine of the Old Glory Gold Mining Co. of Grants Pass is on Silver Creek about 25 miles almost due west of Grants Pass and nearly 20 miles from Galice, from which it is reached by trail. It is the only lode prospect noted on Silver Creek and I did not visit it, but I am informed that there are four claims on the strike of the vein besides a large tract of placer ground. Two tunnels 40 feet in length open up a large quartz vein carrying on the average $10 a ton in free gold and sulphides. Smaller veins near by carry both gold and copper. The ledges run east and west and cut across the formations, which are well exposed on the walls of the canyon.

EUREKA MINE (74).

The Eureka mine on a branch of Soldier Creek, about 12 miles northwest of Kerby, is owned by a company in Eureka, Cal.

The property embraces six or more claims and is reached by trail only. There are probably 1,000 feet of underground workings, also air drills, electric lights, and a 10-stamp mill with concentrator and cyaniding plant now idle. The mine was operated more or less

irregularly for about four years, beginning in 1901, with a Huntington mill. The output, though considerable, is not definitely known.

The country rocks are greenstone and serpentine and the ore occurs in irregular but abundant veins or bunches of quartz on the contact or near it in the adjacent greenstone. The quartz streaked with a dark ore mineral, reputed to be a telluride, is richest and is said to run as high as $500 a ton. Such ore was rare and is not now available. The general average of ore is low, much of it about 40 cents a ton, and would not pay for working. The ribboned veins of quartz strike N. 50° W. and dip 75° NE. The contact has been worked 250 feet in depth and 500 feet in length horizontally.

G. E. ANDERSON PROSPECT (76).

Mr. G. E. Anderson has recently opened a prospect near Illinois River and the mouth of Rancherie Creek in greenstone close to the border of serpentine. The sheared belt of rock, 10 feet in width, carrying a fair grade of ore, runs N. 45° E. and dips 47° SE., approximately parallel with the neighboring contact. Irregular quartz veins occur in about 4 feet of this belt and yield some free gold when mortared and panned. The most prominent ore minerals are pyrite, chalcopyrite, and galena, so that the ore contains copper, lead, and possibly silver, as well as gold. Assays are reported from $1.80 to $180 a ton on picked samples, and the quartz is said to average about $9 a ton.

About a mile farther southwest, on the west fork of Rancherie Creek where it cuts across a point of tuffaceous greenstone flanked by serpentine, a fault in the greenstone is well exposed. The fault runs nearly east and west and dips 68° N. The rock is much crushed, slickensided, and mineralized for a short distance on both sides, but most richly on the fault. In places there is much quartz on the fault plane. The small body of ore along the fault is chiefly pyrrhotite and is said to contain some nickel and free gold. This deposit is evidently related to that on the Calumet in the forks of Rancherie Creek.

CALUMET MINE (77).

The Calumet mine embraces nine claims, extending from Illinois River at the mouth of Rancherie Creek southwest by the forks of the creek for a mile and a half.

The country rock is serpentine and tuffaceous greenstone. The fragmental character of the greenstone demonstrates its volcanic origin and also shows that it is intruded by the serpentine. As a result the greenstone at a number of places on or near the contact is more or less richly mineralized with pyrite, pyrrhotite, and some chalcopyrite and galena.

The principal openings of this mine for pyrrhotite and auriferous chalcopyrite are near the mouth and forks of Rancherie Creek. They are described in this report under the head of "Copper mines," because of their relation to the deposit on Fall Creek. It is reported, however, that most of the value is in gold. (See p. 85.)

The greater underground workings of the Calumet mine are in a hill of tuffaceous greenstone nearly surrounded by serpentine about a mile southwest of the forks, higher up the spur than the outcrops of pyrrhotite. On the summit of the hill is a prominent quartz ledge said to carry $4 to $8 a ton in gold. The hill has been tunneled from all sides by nearly 2,000 feet of workings designed to test its ores. Quartz veins are common and run in various directions from N. 40° W. to N. 70° E., centering in the hill. The best quartz veins visible carry chalcopyrite and galena, but the material generally carries free gold. The hill contains a great deal of low-grade ore that might be concentrated, and if the large 500-foot tunnel now far beneath the summit ledge strikes paying ore it might furnish a convenient means of removing a large body of ore.

CASEY PROSPECT (79).

On the west fork of Rancherie Creek, at an elevation of about 3,200 feet and nearly 11 miles in a direct line northwest of Kerby, a group of six claims is being actively prospected. The openings are near the contact of greenstone and serpentine, and a soft black deposit rich in pyrite has attracted attention on account of its rapid oxidation and the development of heat when exposed. The material had not been assayed at the time of my examination, but when panned and treated with nitric acid to remove the pyrite it yields numerous colors. The serpentine shows some copper stains, and the decomposed greenstone deeply covering the hill slope is said to pan well in free gold. Assays of the ore by a local assayer are said to indicate a content of $60 a ton. Water is being turned on this property to wash the crushed material at the contact.

HIGGINS MINE (80).

The Higgins mine, at the head of Slide Creek on the Chetco side of the divide, 12 miles on a direct line or 20 miles by trail northwest of Kerby, has recently attracted much attention. The holdings embrace 10 claims taken up, at least in part, by L. G. Higgins in 1903. They extend northeast and southwest along a contact of greenstone and serpentine. The contact has been sluiced at a number of places and most of the gold has been won in this way. The gold is very fine and flaky. It has not been transported, but was set free by decomposition of the rocks in place along the contact. The gold does not occur in quartz veins, according to Mr. Higgins, but between the folia of the talcose minerals in the shear zone along the contact.

The latest strike of this mine in the Golden Dream at the head of Slide Creek, at an elevation of about 3,500 feet, has been sluiced by lessees. The ore was rich, but not richer than that obtained by Mr. Higgins years ago on the same contact, three-fourths of a mile farther southwest. Mr. Higgins has erected a 3-stamp mill with a concentrator to mill the contact rock. A 100-foot tunnel, somewhat meandering, has been run along the sheared contact to open it up, but there is no evidence to show the relative value of the rock at and beneath the surface. A short distance west of the earlier mine some slaty rocks outcrop which may be of sedimentary origin, but no gold is reported along their border.

The Higgins mine affords one of the best examples of the general character of the pockety lode-gold deposits in southwestern Oregon.

BLACK BEAR CLAIM.

The Black Bear claim, located on the ridge between Hoover Gulch and Fall Creek, recently yielded some rich samples of free gold that attracted considerable attention. It is described as a well-defined quartz ledge plainly traceable on the surface of the steep mountain slope. The ledge was opened at four different points. It extends northeast and southwest, and where the rich samples were taken it was not less than a foot thick.

HUSTIS AND ANDERSON CLAIMS (81).

The Hustis and Anderson claims are on the northwest slope of the Chetco divide on Miller Creek, nearly a mile southwest of the Higgins claims, at an elevation of nearly 2,300 feet. The main contact of serpentine, running N. 20° E., lies just west of the mine, which is mainly in greenstone. A 100-foot tunnel to the east in greenstone reaches another contact with serpentine.

An old arrastre, now in ruins, gives evidence of milling some years ago. The principal serpentine contact with greenstone extends directly from the Higgins mine to the Hustis and Anderson claims, where it meets another body of serpentine from the east.

MILLER AND BACON PROSPECTS (82 AND 83).

The recent strikes of the Higgins mine have greatly invigorated prospecting in that region, and numerous claims have been located near the same horizon to the south on Miller Creek and Baby Foot Creek, tributaries of the Chetco.

The Miller and Bacon prospects are on the ridge between Miller Creek and Baby Foot. At the northern foot of this spur, along Miller Creek, a mass of serpentine strikes nearly east and west and cuts the volcanic greenstones which form the body of the ridge. The greenstones are well exposed in the great bluffs overlooking Baby Foot and

are intruded by smaller masses of serpentine, offshoots of the larger masses which lie at some distance on both sides.

Considerable quartz occurs in irregular veins or bunches in the greenstone, especially near the contact with serpentine, where it is impregnated with chalcopyrite and pyrrhotite. The veins strike in general about N. 60° E. and dip SE. Their gold content is not evident, though it is said that assays show a considerable amount. The gold at present remains in the decomposed and rotten rock, ready to be released by sluicing.

In the Miller group of 10 claims, a portion of the contact has been sluiced. A ditch is being opened from Miller Creek to the crest of the divide at an elevation of about 2,760 feet, for the purpose of sluicing the available auriferous residual material clinging to the slopes on both sides of the spur.

WILLIAMS & ADYLOTT MINE (84).

A number of claims on Hoover Gulch, about 8 miles directly northwest of Kerby, are owned by Williams & Adylott. The claims were seen from a distance only. The country rock is mainly greenstone and greenstone tuffs, which are well exposed in the bluffs about the head of the gulch, but there is an intruded mass of serpentine also in the neighborhood, and possibly, too, some cherty slates and quartzites related to those at the head of Hoover Gulch.

A shaft has been sunk 40 feet in rock that is said to contain gold all the way down. The residual material has been piped off and $500 cleaned up, though much of the gold is reported to have been lost.

GOLD RIDGE PROSPECTS (89).

Pocket Knoll and the divide between Mike and Days gulches, 5 to 7 miles northwest of Kerby, have long been noted for their pockets of free gold. Pocket Knoll is composed of serpentine with a greenstone contact near its western base. From this contact northwest on the divide, to the head of Hoover Gulch and beyond, the ancient lavas and tuffs include much reddish and siliceous slates of sedimentary origin. The cherty masses, especially about the head of Hoover and Mike gulches, have recently been prospected. With a small hand outfit consisting of a Simplex rock crusher weighing 150 pounds, and a 25-pound muller and plate for pulverizing, T. M. Anderson, of Kerby, is said to have taken much gold out of a number of rich pockets.

There are a number of claims, four or more, on the flat divide at the head of Hoover and Mike gulches. The divide is occupied by a belt of more or less cherty slates, about 100 feet in width and covered by a thick layer of rotten rock, bounded on both sides by greenstone with serpentine near by to the northwest. The greenstone is

in places granular but mostly compact and in general contains much auriferous pyrite. The cherty belt and its quartz veins trend N. 20° E. and dip 50° SE. A tunnel is being run across the belt in the rotten rock to locate the richest portion. A shaft has been sunk 20 feet in this soft rock and gold has been panned from the oxidized material at the bottom. The little swale on the northwest has been sluiced with good returns, and if water were cheaply available it is possible that considerable pay ground could be found.

A short distance northeast of the tunnel mentioned above is the "Beauty" claim, on which a pocket recently opened is said to have yielded $5,000 or more of free gold in quartz. The country rock is compact greenstone lying east of the siliceous slates, and the narrow pay streak, about 10 feet in length and within 2 feet of the surface, runs northwest and southeast perpendicular to the general course of the formations.

PHILIPS PROPERTY (90).

The Philips property, known also as the Vanguard, is on the north slope of Days Gulch near Pocket Knoll. Several openings have been made in the hillside and an 80-foot tunnel run in greenstone not far from its contact with cherty slates. Some sulphide ores carrying copper and gold were obtained, although no considerable bodies were visible at the time of my examination. The tunnel is to be extended 500 feet farther into the hill. A small and very crude arrastre on the creek is said to have been used to grind some of the pocket ore from the ridge near the knoll.

CHATTY MINE (91).

The Chatty mine is situated in Days Gulch, nearly 5 miles northwest of Kerby at an elevation of 3,160 feet. The country rock is greenstone and is much decomposed near its contact with serpentine, where the original owner some years ago found a rich pocket which is reported to have yielded approximately $8,000.

The mine was worked to a depth of 30 feet before it came into the hands of the present owner, who has run a tunnel 110 feet to a fault with a well-defined gouge, but no valuable ore is yet in evidence. The fault runs N. 4° W. and has a steep dip to the west, being approximately parallel to the adjacent contact between the greenstone and serpentine.

This pocket, of small extent, was in oxidized material and its contents were completely removed some years ago. Early prospectors found traces of gold on the surface. Later these traces were followed to a depth of 15 or 20 feet into the oxidized rock, where in the rich pocket the quartz veins were found rusty and black. The quartz in the vicinity is porous, and where compact between the cavities is fairly rich in pyrite. The cavities are lined with quartz

crystals, generally coated with limonite like that filling the late fissures in the rock. No free gold was seen with the quartz in any of the cavities, although pocket hunters of the region assert that such quartz is characteristic of pockets. An extension of the pocket has been sought for in all directions, apparently without avail, although the work continues.

MOOD MINE (92).

Near the forks of Fiddlers Gulch, about 7 miles nearly west of Kerby, are situated the six claims of the Mood mine. Like most of the lode mines of that region this mine is in the vicinity of the western border of the great serpentine belt. It is said that the mine has nearly 2,000 feet of underground workings and an old arrastre in which ore was ground that yielded some thousands of dollars. Tunnels are being run to the northeast along a shear zone approximately parallel to the contact. There is a small but distinct gouge, some irregular veins of quartz, and a lens of very hard rock rich in pyrite.

In the same vicinity but farther west, between the forks and along the main branch of Fiddlers Gulch, there are a number of openings that were not seen, among them those of Watson and Andrews (93). The greenstone is in places full of pyrite, but its value has not been proved.

NEIL MINE (94).

On the south fork of Fiddlers Gulch, at an elevation of nearly 2,400 feet, 6 miles west of Kerby, is the mine owned by Neil Bros. and recently sold to the Segno-Tomek Gold Mining & Milling Co. for $80,000 according to report.

The discovery of the Neil mine was made by a short tunnel that yielded, it is said, some remarkably rich dark telluride ore. The discovery tunnel is near the contact of the greenstone and serpentine. It has caved in, water issues from it, and the rich ore reported is inaccessible at the present time.

The Segno-Tomek Co. has run a large tunnel N. 68° W. for about 300 feet to a contact and then followed the contact south for nearly 100 feet in an attempt to strike the rich ore several hundred feet beneath the original discovery.

The rocks along the contact are much crushed and for 6 to 12 inches have much sheared material which is decidedly serpentinous. As far as seen it contains little evidence of ore.

CANYON CREEK CONSOLIDATED GOLD MINES (95).

The property of the Canyon Creek Consolidated Gold Mines Co. embraces seven claims near the head of the North Fork of Canyon Creek, about 8 miles directly west of Kerby, at an elevation of about 2,900 feet.

After a number of prospect openings, more or less promising, were made high up on the slope a tunnel was run 500 or 600 feet below to find their downward extension. The tunnel is of good size and 300 feet long in greenstone. No important body of ore has yet been reached. A small stringer was cut, yielding $65 in gold and silver to the ton. About 90 feet of the rock tunneled is more or less impregnated with pyrite and is said to assay from $2 to $4 to the ton. It is proposed to continue the search for the rich ore.

An opening on the creek nearly a mile above the mine exposes a slickensided fault plane striking N. 60° E. and dipping 60° SE.

BOWDEN PROSPECTS (96).

Mr. Samuel Bowden, of Grants Pass, has opened a number of claims on the North Fork of Canyon Creek and Lightning Gulch, in greenstone on shear zones, veins of quartz or dikes of dacite porphyry cutting the greenstone, and reddish cherts that are radiolarian and certainly of sedimentary origin. In all these places the greenstone is more or less impregnated with pyrite and in some of them with chalcopyrite. The shear zones and quartz veins run N. 20° E. and dip 40° SE. The greenstone in places is practically a chlorite schist and is then most probably full of pyrite. The reddish chert is closely related to that of the Pocket Knoll region and lies only a short distance beyond the western limit of the great serpentine belt that crosses the North Fork of Canyon Creek at the falls, half a mile above its mouth.

In the same region the Telluride Gold Mining Co., of Seattle, has five claims. It is reported by Mr. Bowden that several tons of ore were shipped to Tacoma as a test and yielded good returns.

WINTERS AND McPHERSON PROSPECTS (97 AND 98).

Lightning Gulch is a tributary of Canyon Creek west of the serpentine belt and traverses essentially the same horizon as the north fork. The greenstones are greatly sheared and cut in some places by dikes related to dacite porphyry. Near by are banded siliceous rocks which resemble quartzites and probably, like the cherts of the North Fork of Canyon Creek, belong to sedimentary masses.

Near the mouth of Lightning Gulch, J. A. Winters has run a number of prospect tunnels into black slates or along their contacts with greenstone. The rocks at this place are much disturbed by slides, and although they may in some places average several dollars a ton, the source of the gold is difficult to trace. Some of the gold, however, appears to be in the slates, whose bronze slickensides are due to shearing movements after the deposition of the ore.

Some distance up Lightning Gulch Eugene McPherson has a mine tunnel 200 feet in length that follows the contact between greenstone and banded quartzite. The greenstone is greatly altered and the contact is very irregular. A small quantity of rich telluride ore is

reported to have been stoped from this tunnel. I was unable to obtain a sample of the ore at the mine, but a small fragment was given me by Mr. Bowden, who assured me that it came from the McPherson tunnel. Mr. Bowden also gave me a sample from his own prospect farther northwest on Lightning Gulch. Both samples reacted strongly for tellurium, giving a decided purple solution when boiled in concentrated sulphuric acid.

ALTA MINE (107).

The Alta mine on Josephine Creek, 4 miles west of Kerby, consists of three claims. For some years the mine was worked only as a placer, but recently a lode mine was opened in the bluffs bordering the placer and a mill erected to crush the ore.

The country rock is serpentine derived from peridotite and cut by a large dike composed of a rock related to dacite porphyry. The dike ranges from 25 to 40 feet in width between serpentine walls and is practically vertical. It strikes N. 40° E. and has been traced by Mr. Wilson about a mile and a half. Many smaller parallel dikes of the same material cut the serpentine of that region, so that the relation of the ore-bearing rock to the serpentine is evident.

The ore is chiefly pyrite, occurring in scattered grains through the rock and more abundantly in small quartz veins, apparently with some chalcopyrite and possibly pyrrhotite. In some places when the rock is pulverized and panned it is found to contain not only pyrite but apparently considerable free gold. As the mine is in the early stage of its development, little is known of the distribution and extent of the disseminated ore. A good sample of the fresh rock with conspicuous blotches and scattered grains of pyritic ore in joints and veinlets of quartz was assayed by E. E. Burlingame & Co., of Denver, for the Geological Survey, and it yielded 0.02 ounce in gold per ton. About a dozen sectional samples assayed by local assayers were reported to me by Mr. Wilson, and they averaged about $5 in gold per ton.

A "Lane slow-speed Chilean mill" has been erected to crush the ore. The rock is first run through a breaker, and after it issues from the mill is run over plates to Johnson concentrators. The mill is run by a 25-horsepower steam engine and has a capacity of 40 tons in 24 hours. Mr. Wilson reports a satisfactory test run of about 500 tons, made in the fall of 1911, at a cost of 80 cents a ton by water power and $1 a ton by steam. After amalgamation and concentration the tailings are reported to show no trace of gold. The overburden of the mine is gravel, and during the winter the water is used for hydraulicking.

ROSEBURG AND FIDELITY GROUPS (113).

The Roseburg group of six claims and the Fidelity group of four claims lie about the head of Tennessee Gulch, 3 miles southwest of Kerby, at an elevation of nearly 2,500 feet.

These claims cluster about the southwest end of an area of granular greenstone surrounded by serpentine whose relations were not fully determined.

Portions of Tennessee Gulch have afforded rich placers. Claims were taken up and a little arrastre built 40 years ago near the head of the gulch. Two tunnels have been run, one N. 70° E. and the other N. 70° W., near the contact of the greenstone and serpentine. The cellular quartz veins containing free gold are in the greenstone and are approximately parallel to the irregular contact, ranging from N. 50° to 80° E., with nearly vertical dip. Pyrite is the most abundant ore. No distinct trace of copper minerals was observed.

A large tunnel is being run at a considerably lower level. It is already in 170 feet in greenstone and nearing the supposed horizon of the veins which appear at the surface.

FREE AND EASY MINE (114).

The Siskiyou Sunset Mining & Development Co. has a deserted mine, generally known as the Free and Easy, in the large serpentine area 2½ miles west of Kerby. Several tunnels and other openings were made in the serpentine on the south slope of the ridge, but they are now caved in. In the valley, a few hundred feet below the mine, there is a small Huntington mill long unused.

OTHER MINES.

Unfortunately I do not have the exact location of the Brooklyn pocket mine and the January mine of the Sucker Creek district. Both mines appear to be west of the Grants Pass quadrangle and reported a considerable production in 1910. According to the latest report from the Kerby district, the only producing mine in that region at present is on Sucker Creek. From this mine Harry Siskron and his partner obtain a few thousand dollars' worth of gold each year with an arrastre.

COPPER MINES AND PROSPECTS.

COPPER PRODUCTION.

In 1905 Oregon became a considerable producer of copper. The reported output for succeeding years is as follows:

Production of blister copper in Oregon from 1905 to 1910.

	Pounds.		Pounds.
1905	846,815	1909	235,000
1906	415,803	1910	13,861
1907	554,104	1911	93,136
1908	291,377	1912	260,429

Except in 1909 and 1910 the greater part of the production came from Josephine County.

COPPER DEPOSITS.

DISTRIBUTION.

The copper deposits of southwest Oregon have long attracted attention and a number of attempts have been made to mine them in a broad belt that extends northeast and southwest from Curry and Josephine counties into Coos and Douglas counties. The earliest attempt was made on Illinois River near the mouth of Rancherie Creek, and later in the same district on Fall Creek, where small furnaces were erected and operated for a short time on the ores of that vicinity. Shipments of ore are reported to have been made from Collier Creek and Rogue River in Curry County by the late Col. I. N. Munsey. At Drew, and on Green Mountain east of Glendale, and the west fork of Cow Creek, near Mount Bolivar in Douglas County, as well as at several points on Chetco River in Josephine County, openings have been made and ores of copper taken out, but all these points are reached by trail only. Extensive developments have been made at Almeda, near Galice, and at Takilma, near Waldo, where smelters have been operated at intervals for a number of years. Both points are easily accessible by wagon road and are now apparently the most active mining centers of the region. For a list of the copper mines and prospects of the Galice-Kerby-Waldo region, see Plate VI, page 46.

GENERAL CHARACTER.

Only a few localities have been examined, and these not in detail, but enough has been seen to indicate that they are essentially contact deposits and that there are two distinct modes of occurrence. In the one class the ore bodies, chiefly pyrite with subordinate chalcopyrite and bornite, occur in quartz porphyry near its contact with slates. In the other class the ore bodies, chiefly chalcopyrite and pyrrhotite, prevail in greenstone or serpentine near their contact.

Of the occurrence in quartz porphyry the deposit at Almeda is the best known and almost the only example in the district; of the occurrence in greenstone or serpentine near their contact the mine at Takilma, generally known as the Queen of Bronze, has been most fully developed and described,[1] but the deposit on Fall Creek is quite as characteristic.

ALMEDA MINE (30).

GENERAL FEATURES.

The Almeda mine is owned and operated by the Almeda Consolidated Mines Co. It is located on the right bank of Rogue River, about 26 miles below Grants Pass, and is reached by stage line and

[1] This mine is described by G. F. Kay in U. S. Geol. Survey Bull. 380, pp. 76-78, 1909.

wagon road 17 miles from Merlin, on the main line of the Southern Pacific. A shorter road (15 miles), avoiding the river but crossing the divide to the railroad at Leland, was partly completed in 1911.

The situation of the mine is advantageous, as it lies in the rugged but passable canyon of a rushing river, cutting directly across the formations, so that the canyon walls afford convenient facilities for economical mining.

My examination of the mine was made rather inopportunely on July 10 and 11, 1911, just as the management changed. At that

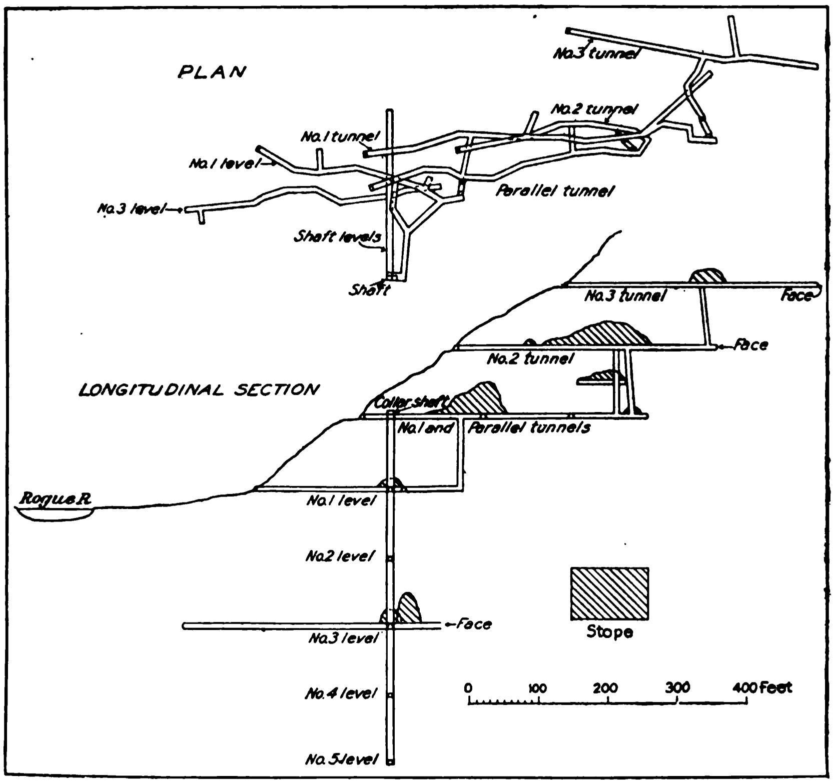


FIGURE 8.—Plan and longitudinal section of Almeda mine. By P. H. Holdsworth, November 28, 1911.

time no plans or sections of the mine were available and considerable portions of the mine were inaccessible, but since then very important development work has been carried on, giving more definite information concerning the ore bodies.

A special survey of the mine was made for the company in the summer and fall of 1911 by Mr. P. H. Holdsworth, and he has kindly furnished me the plan and longitudinal section (fig. 8) of the mine. Furthermore, he sent me numerous assays of the ore and much other information quoted below concerning the adjacent rocks.

It is only fair to Mr. Holdsworth to give his own statements in a letter of November 28, 1911, concerning the plan and sections. He says:

I had only one day to make it in from my notes, and it is far from complete, but it will give you an idea of the workings and ore bodies, as to size, etc. It is not complete in that it does not show the continuation of tunnel No. 1 and the 100-foot level (river tunnel). Those are driven to the north several hundred feet, but the air in them was so bad at the time of survey that I could not use the transit.

The ore deposit on which the mine is located contains gold, silver, and copper, and lies along an eruptive contact on which there has been considerable faulting.

The Almeda mine is developed by extensive underground openings more than 1,000 feet in length on the strike and 800 feet in depth by adit tunnels above the river and by a vertical shaft reaching nearly 400 feet beneath the river, with crosscuts and levels every 100 feet, as shown in the plan and longitudinal section prepared by Mr. Holdsworth.

The mine is near the southwest border of the Galice formation (dark slates) along its contact with an igneous rock, but for the most part within the igneous rock, on what is generally known in the region as the Big Yank lode. The igneous rock at the mine is closely related to quartz porphyry or alaskite. When fresh the rock has a dark-gray color, but in most places it is bleached and stained various shades of gray, green, yellow, or red. In places its texture is sparingly porphyritic, with phenocrysts of quartz and feldspar, generally plagioclase, embedded in a very fine granular or cryptocrystalline groundmass of quartz and feldspar, which in most places forms the bulk of the rock. It is much cut by shearing planes and deeply affected by oxidation, though as it is highly siliceous it resists disintegration and forms ledges on the surface.

Faults are common in the slates near the contact, and occur also in places between the slates and the lode. By the road just east of the shaft house two small parallel overthrust faults displacing a dike in the slates were measured. They strike N. 15° E. and dip 50° NW. with an underthrust of 4 feet to the northwest. Similar faults may be expected in the mine.

The slates near the contact are in places markedly indurated by the intrusion of the quartz porphyry. On the 300-foot level, within a foot of the contact, the slates, usually dark, are baked light gray, and very hard. They are seamed with calcite, especially on the shearing planes.

The contact between the slates and the igneous rock, with which the Big Yank lode is associated, may be traced for over 20 miles in a direction about N. 30° E. from Briggs Creek valley to Cow Creek at Reuben Spur. Although the general course is maintained with con-

siderable regularity, there are many small variations, and the contact dips to the southeast in the same general direction as the slates. The plane of contact is generally a fault plane and is for the most part followed by the lode. The contact is apparently most irregular and the quartz porphyry most cut by shearing planes in the vicinity of the ore bodies.

According to Mr. Holdsworth the 96-foot crosscut west from the 500-foot level traverses "metamorphosed slate" and the contact is still farther west, beyond the end of the crosscut.

I visited the 500-foot level and followed the crosscut from the shaft westward 96 feet to the end, collecting samples at both ends and at two intermediate points. By the shaft the rock is in some places impregnated with pyrite to such an extent that nearly one-fourth of the mass is pyrite. There is much less pyrite 12 feet from the shaft, and from that point to the western end of the crosscut pyrite, though present, is less conspicuous.

A white mineral occurs in this crosscut more or less abundantly throughout the rock in veinlets and small bunches and appears to increase in quantity toward the western end. This white mineral was found to be gypsum, probably derived, as Graton[1] has shown, from anhydrite.

The samples taken on the 500-foot level near the shaft and 12 feet west of the shaft were assayed by E. E. Burlingame & Co., who report a gold content of 20 cents a ton in each. One of the samples contained a trace of silver.

The rock traversed by the crosscut for 96 feet west from the shaft on the 500-foot level is highly siliceous. In the mine I regarded it as quartz porphyry and not metamorphosed slate, as considered by Mr. Holdsworth. The contact of the quartz porphyry with the slates on the 500-foot level appears to me to be at the foot of the shaft. In this view I have been confirmed by a microscopic study of thin sections of the rocks collected along the crosscut. The rocks still retain much of the original structure of the quartz porphyry impregnated with pyrite and are strongly contrasted with samples of the indurated slate found elsewhere in the mine.

With due regard to the much more extended investigations of Mr. Holdsworth, I am still of the opinion that the ore horizon is on the contact near the foot of the shaft on the 500-foot level.

CHARACTER OF THE ORE.

The ore minerals are sulphides, and the ore appears to be of two types—one copper ore with barite as the principal gangue mineral, and the other siliceous gold-silver ore, reported by Holdsworth but

[1] Graton, L. C., The occurrence of copper in Shasta County, Cal.: U. S. Geol. Survey Bull. 430, p. 103, 1910.

which I have not seen in place. The latter ore is principally valuable for its gold and silver and has quartz as the gangue.

The copper ore is rich in pyrite and barite, usually having a smaller percentage of intermingled chalcopyrite and in places some bornite. Gray copper ore, tetrahedrite, has been reported, but its presence could not be demonstrated.

Rich copper ore was noted near the indurated slates on the 300-foot level, a short distance north of the crosscut from the shaft.

The ore throughout is of the replacement type and is in general an altered and mineralized porphyry.

A partial analysis by Chase Palmer, of the Geological Survey, of a sample of this ore which I collected on the 300-foot level just north of the crosscut from the shaft gave the following results:

Analysis of ore from the Almeda mine, Oregon.

SiO_2	0.31
$BaSO_4$	68.21
CaO	1.01
Cu	6.02

The same material assayed by E. E. Burlingame & Co. gave gold 0.10 ounce and silver 7.78 ounces to the ton.

This sample was evidently one of the best of the baritic ore. It is high in both copper and silver and carries enough gold to pay for its extraction.

As far as they go the above determinations accord with the following information furnished me by Mr. Holdsworth concerning the value of the copper ore. Mr. Holdsworth states:

To the west of the metamorphosed slate is the heavy spar-iron-copper ore. This runs from 6 to 20 feet in width.

Analyses of copper ore of Almeda mine.

SiO_2	8.8– 5.1
FeS_2	27.0– 48.1
CaO	0.8 to trace.
$BaSO_4$	47.8– 28.2
Al_2O_3	8.0– 10.9
$CuFeS_2$	6.4– 6.8

Assays of copper ore of Almeda mine.

Cu	1.5 to 4.5 per cent.
Au	0.12 to 0.42 ounce per ton.
Ag	3.32 to 12.18 ounces per ton.

Lime runs up at times to 2 per cent.

Concerning the siliceous gold-silver ore Mr. Holdsworth remarks:

Lying next to and west of the spar ore is from 30 feet (in the parallel and No. 1 tunnels) to 60 feet (in the 300-foot level) of a siliceous gold-silver ore. The 300-foot level

was driven 120 feet farther to the west after you were here, and all in commercial ore. No footwall yet. The "porphyry" at this point has been entirely replaced by the siliceous ore, but comes in again on the south drift on this level.

In the upper levels the siliceous ore averages as follows:

Average analysis of siliceous gold-silver ore of Almeda mine.

SiO_2	62.9
FeO	11.5
CaO	2.1
BaO	8.1
Al_2O_3	5.6
S	8.3
Cu	0.3°

Assay of siliceous gold-silver ore of Almeda mine.

Gold	0.14 ounce per ton.
Silver	6.40 ounces per ton.

In the lower levels this ore gives about the same analyses, but the gold content is very much higher. In fact, the muck from the 120-foot crosscut west from the 300-foot level, where you saw it, was all run through the smelter, and though the shoot proper at this point is only about 60 feet wide the muck from the 120 feet averaged: Au, 0.90 ounce; Ag, 3.2 ounces; Cu, about 0.3 per cent. In fact, the ore body at this point has the greatest showing that I ever saw in any property.

Still to the west of this porphyry intrusive is ore similar in character to the siliceous ore. I have no idea of its extent, or the distance to the footwall, as work has not been sufficient to prove it. Drifts have been run 65 feet west from the porphyry and no wall. The ore to the west has not been sampled sufficiently to give a true idea of its value, but what samples I have taken lead me to think that it can be worked at a profit.

In the samples I am sending, Nos. 6, 7, 8, 9, and 10 are representative of the siliceous ore. Nos. 9 and 10 have the values labeled on them. The others have not been assayed, but are typical of the ore and may run anywhere from $4 to $1,000 per ton.

Sample No. 9, mentioned above by Mr. Holdsworth, is labeled: "300-foot level, gold, 18.64 ounces per ton; silver, 5.90 ounces per ton."

Sample No. 10, mentioned above, is labeled: "300-foot level, gold, 9 ounces per ton; silver, 5.96 ounces per ton."

An assay of sample No. 9 was made for the Geological Survey by E. E. Burlingame & Co., who reported it to contain 16.88 ounces of gold and 10.92 ounces of silver to the ton. Samples Nos. 6 and 8, referred to above with Nos. 9 and 10 as representative of the siliceous ores, but not definitely located in the mine, were assayed for the survey by E. E. Burlingame & Co., who reported as follows:

Sample No. 6: Gold, 0.48 ounce to the ton, and silver 0.52 ounce to the ton.

Sample No. 8: Gold, 0.075 ounce to the ton, and silver only a trace.

This gives a range from $1.50 to nearly $10 a ton in gold.

Practically all the samples of ore I collected in the Almeda mine comparable with those sent to me by Mr. Holdsworth are of the

baritic type. The only siliceous material I collected was taken from the crosscut west from the 500-foot level, and thin sections show this to be quartz porphyry impregnated and partly replaced by a very low-grade pyritic ore. The assays of these specimens given on page 77 show that they contain but very little gold and only a trace of silver.

These samples, however, appear to me to fairly represent much of the material lying immediately west of the copper ore and contact. For example, it is well exposed on the surface by the river and up the slope by the mine, especially on the road near the smithy, where the quartz porphyry is impregnated with pyrite more or less irregularly for more than a hundred feet from the contact, but the great body of impregnated rock, judging from its physical aspects, does not appear to carry important ore.

The ore occurs in "bunches," as the miners phrase it, "that are longest up and down and shortest directly across the contact." The shape and extent of the ore bodies have not yet been definitely worked out for lack of sufficient development, but they appear to me to be in general lenticular in form, with their greatest extent in the plane of the contact, and pitch to the southwest approximately parallel to the slope of the surface.

The thickness of the principal ore body where I saw it on the 300-foot level is about 15 feet. As shown in the crosscuts from the contact to the porphyry dike the thickness of the ore body, according to Holdsworth, ranges from 15 to 50 feet. The greater dimensions he reports I have not been able to verify, nor have I seen the dike and the great body of siliceous gold-silver ore which he reports west of the dike on the crosscut from the 300-foot level. The western extension of the crosscut on that level was made since my examination. On the western side the ore bodies appeared to me to grade more or less distinctly into the quartz porphyry.

The horizontal extent of the ore body along the contact is said to be about 225 feet. Along the contact, parallel to the slope of the surface, the ore appears to have its greatest extent, or pitch, with a possible but irregular continuity of about 600 feet from the shaft crosscut on No. 1 level to the stopes in tunnel No. 3, and beyond to the gossan on the surface, nearly 400 feet above the level of the river. The greater prominence of the gossan on the upper slope northeast of the shaft is evidence that ore shoots rise in that direction.

It seems probable that there is a second ore shoot farther northeast than the one just noted, for Mr. Holdsworth, in writing of the continuations of tunnel No. 1 and level No. 1 to the north, states as follows:

They show, however, the same character of ore as in the other workings, and also a second shoot of ore parallel to that shown by the stopes in the different levels and

lying approximately with the slope of the hill. It may be, however, that it is a continuation of the same shoot to the north, as on the No. 2 tunnel level the ore is continuous and massive for a length of 225 feet and shows in the tunnels at intervals as far north as what I called the second shoot.

If the upper shoot really lies, as it seems to me, with the longest axis parallel to the surface, then the rich ore body on the 300-foot level would appear to belong to a deeper shoot, a shoot possibly connecting with that referred to above by Mr. Holdsworth as a "second shoot." If such is the case, the ore deposit on the 500-foot level would be most likely to occur 200 feet or more south of the shaft.

The absence of a considerable body of ore at the contact by the shaft on the 500-foot level does not therefore necessarily mean that ore does not go down to greater depths, for according to the pitch of the ore shoots just noted the ore should be looked for in the contact along the 500-foot level south of the shaft.

Definite walls limiting the ore bodies appear chiefly, if not wholly, on the east side, adjoining the slates, where there has been faulting, which at a number of places has produced a definite gouge. Where such gouge is absent on the contact there is still a marked boundary between the ore body and the slate, but on the west side, as far as observed, the ore appears to grade into country rock richly impregnated with pyrite.

The gossan is well exposed in an open cut 12 feet wide to the depth of 15 feet. It is strongly stained yellowish and brown by limonite and is composed largely of barite in small crystals or porous tufa-like masses. This highly baritic gossan may be 20 to 50 feet thick, but could not be thicker than 80 feet below the gossan opening, for at that level tunnel 3 on the strike of the ore brings out fresh pyrite, showing no trace of oxidation. A zone of enrichment is not exposed. If one is present it occurs in the steep slope several hundred feet above the river and the ground-water level at that point. The porous barite of the gossan is a secondary deposit, though derived directly from the pyritic ore, of which it is the gangue.

ORIGIN OF THE ORE.

The altered quartz porphyry, well exposed at the mine, is impregnated with pyrite more or less irregularly, in some places for more than 100 feet from the contact, and the amount of pyrite generally increases toward the contact, where the conditions under which it was deposited were most effective and resulted locally in completely replacing the country rock, quartz porphyry, by the development of bodies of pyritic ore. The ore bodies are not veins marked by sharp walls, but while they grade into the quartz porphyry on the one hand they are more distinct from the slates on the other. Some

of the ore bunches may be completely surrounded by quartz porphyry, but they were not seen to extend into the slates. The slates are cut by dikes of dacite porphyry near the contact. Several of these dacite porphyry dikes are well exposed in the road bluff by the shaft house, and one that is greatly altered and full of vein quartz with disseminated pyrite may be seen in the slates of the mine on the crosscut to the 100-foot level.

The close relation of the dikes of dacite porphyry and the ore body is regarded as indicating that the ore deposit is the final term in the series of changes started by the intrusion of the porphyry dike.

This intrusion heated the rocks and initiated the circulation of heated solvents, which while dissolving some minerals deposited others in their stead, and the process may have been carried on until the originally intruded rocks, dacite porphyry as well as the quartz porphyry, may have been completely replaced by various ores.

THE SMELTER.

Near the mine and conveniently located on the river there was, in 1911, a small smelter with water-jacketed furnace for treating the ores. The first attempts at smelting this ore in 1911 were not successful. Concerning the later operations, Mr. Holdsworth writes:

Outside of trouble with one car of bad coke (28 per cent ash) I had no trouble other than would naturally occur with a small furnace. I used the siliceous ore as a flux for the iron and spar and used no lime whatever, except the small amount in the ore.

The furnace is 36 inches by 72 inches at the tuyères, and we averaged a little over 100 tons a day—that is, 100 tons of ore besides the coke and slag. Ran semipyritic smelting ore from 6 to 7 per cent coke. As the iron and barium occur as sulphides and sulphates, respectively, there was about 26 per cent sulphur in the charge. Could average about 30 tons a day more when running semipyritic smelting than when running straight coke smelting.

The following are typical slags:

Composition of slags from smelter at Almeda mine.

	1	2	3	4
SiO_2	30.9	31.8	31.1	38.9
FeO	24.9	24.0	25.3	22.3
CaO	3.1	3.9	4.8	1.3
BaO	30.4	26.9	29.1	32.9
Al_2O_3	10.6	13.5	9.9	4.7

Though percentage of BaO and alumina is high, they run very well, with seldom a loss of 0.3 per cent copper; usually from 0.15 per cent to 0.2 per cent copper. Ratio of concentration from 12 to 1 to 20 to 1.

It is reported that in 1913 the smelter produced 6 carloads of matte, valued at about $40,000. On August 23, 1913, the property of the Almeda Mines Co. passed into the hands of a receiver, who,

after making a 3 weeks' run of the smelter and producing 3 carloads of matte, closed the smelter to make some tests in concentrating the ore and to erect a concentrating plant.

QUEEN OF BRONZE MINE (119).

In the great serpentine belt extending southwest through Josephine County into Curry County and into California there are numerous copper prospects, of which those in the vicinity of Takilma, southeast of Waldo, are most important. The description of the Queen of Bronze and neighboring mines given below is taken from a report by G. F. Kay.[1] The mines and smelter were in more or less continuous operation from 1906 to 1909, inclusive, and then closed.

The Queen of Bronze mine is located in sec. 36, T. 40 S., R. 8 W., about 6 miles from Waldo and 2 miles from Takilma.

The rocks with which the ores are associated are gabbros, peridotites, and serpentines. They are fractured, fissured, and jointed, and in many localities are decidedly brecciated. The soil formed from these rocks is in general of a reddish color and supports a scant vegetation.

The outcrops of the ore deposits consist of gossan, the oxidized materials varying in depth from a few feet to more than 100 feet. The ore bodies have no definite form, but occur as irregular masses in the gabbro, the peridotite, and the serpentine. These masses or pockets of ore appear to have no definite relationships to one another, but occur irregularly in the fractured and fissured rocks. Most of the ore bodies, however, that have been found on the Queen of Bronze and adjacent claims lie in a zone that extends for several miles in a north-south direction and has a width of less than 1 mile. The largest single body of unoxidized ore obtained from the Queen of Bronze mine contained about 10,000 tons. Practically all of it came from a depth of less than 30 feet. Other masses of unoxidized ores have been taken from depths of about 100 feet. Although depths of about 300 feet have been reached in the workings, no important body of ore has been found below 125 feet. Several occurrences of slickensided ores were observed, and in some places the ore contains small veinlets of calcite.

The unoxidized ore is chalcopyrite, with which are associated pyrite, pyrrhotite, and subordinate amounts of quartz and calcite. In the low-grade ores pyrite and pyrrhotite are the most abundant minerals. In addition to the copper content the ores carry some gold and silver.

The oxidized ores are malachite, azurite, cuprite, tenorite (?), and chrysocolla. Of these the black ores containing tenorite or chalcocite

[1] U. S. Geol. Survey Bull. 380, p. 76, 1909.

are most abundant. Several thousand tons of oxidized ore has been mined. The average content in copper was more than 10 per cent. The lower limit of the oxidized ores is usually less than 90 feet from the surface, but some have been found at greater depths. In a small opening about 105 feet below the surface black oxide and small amounts of native copper were observed. The zone of oxidation is invariably deeper where the rocks have been serpentinized than where the country rocks are fairly fresh.

These ore bodies are apparently the result of precipitation from mineral-bearing solutions which entered the rocks after they had been fractured and fissured by earth movements. Whether these solutions were set free from cooling magmas as they solidified to form igneous rocks or whether they were of meteoric origin it is impossible to determine. Although dikes cutting the peridotite and gabbro were not observed in the vicinity of the mine, their presence in other areas of these rocks would suggest that the solutions may have been associated with the magmas from which the dikes were formed. In places in the serpentine below the zone of oxidation chalcopyrite with slickensided surfaces has frequently been found. The chalcopyrite appears to have been subjected to all the movements which accompanied the process of serpentinization. This indicates that the ores are older than the serpentine.

The mine is more than 20 miles from Grants Pass, which is the most accessible point on the railway. The only means of transportation between Grants Pass and the mine is by wagon, consequently the rates for hauling machinery, provisions, and other materials for the mine and coke for the smelter have been high. This fact has been unfavorable to the development of the property. The mine is situated on the slope of a ridge. The smelter is at the base of the slope, 500 feet below the mine and 1½ miles from it. The ores, when taken from the workings, are trammed to bins, from which they are transferred to wagons and hauled to the smelter.

The equipment at the mine consists of three boilers, an air compressor, a hoist, and two machine drills. The mine has been developed by tunnels, drifts, and open cuts. The chief workings are near two gossan-covered areas on the claim. The northern and more extensive workings are near the north boundary of the claim; the other workings are about 1,200 feet farther south.

The northern workings consist of two tunnels, from which considerable drifting has been done, and a large open pit. The upper tunnel, which is about 400 feet long, enters the west slope of the ridge and runs eastward beneath an area of decomposed and brecciated gabbro, in which are oxidized ores. At no place does this tunnel have a vertical depth of more than 90 feet from the surface. In this tunnel and in drifts and winzes from it some large irregular-shaped

masses of chalcopyrite, but practically no oxides, were obtained. From the tunnel an upraise was made to the oxidized ores. This upraise was then used as a chute. The oxidized ores were mined to the surface by overhand stoping, passed through the chute, and carried out by tram through the tunnel. Several thousand tons of oxidized ores were mined in this way, the large open pit thus formed having an area of about 120 by 120 by 80 feet. Where the tunnels and other workings were in the serpentine, great care had to be taken in timbering. The lower tunnel also enters the west slope and is about 190 feet below the upper tunnel. In it and in drifts from it more than 1,100 feet of work has been done. Only a small amount of ore was found in these workings.

The southern workings consist of a large open cut, a tunnel which runs underneath this cut, and a 106-foot shaft. From the open cut about 10,000 tons of unoxidized ore, carrying about 7 per cent of copper was taken. The zone of oxidation was only a few feet in depth. The ores mined were passed through a chute from the bottom of the pit to the tunnel and then trammed to the bins. From the tunnel and the shaft only a small amount of profitable ore was mined.

All the ores that have been mined have been smelted at the Takilma smelter, which is under the same ownership as the mine. The smelter is of the pyritic matte type and has a capacity of 100 tons a day. The charge used was about 1,500 pounds of ore, 350 pounds of limestone, and 200 pounds of coke. The limestone used had to be hauled about 2 miles. The matte from the ores smelted in 1907 contained about 40 per cent of copper.

The Queen of Bronze property was acquired in 1903 by the present (1910) owner. Only a small amount of development had been done on the property previous to its acquisition. In all, about 30 claims are owned by the company. Including the cost of the smelter, more than $150,000 has been spent on the properties. Mr. Tutt, the president of the Takilma Smelting Co., stated that more than 20,000 tons of ore had been smelted and that the average copper content had been about 8½ per cent. The gold content of the ores has been worth more than $3 a ton, the silver content about 17 cents a ton. Ore was first smelted from this property in 1904. The greatest production was in 1907.

OTHER COPPER PROSPECTS IN THE WALDO REGION.

As already stated, there are several small mines adjacent to the Queen of Bronze mine. Considerable development has been done on these properties, and from three of them—the Cow Boy, the Lyttle, and the Mabel—about 4,000 tons of ore had been smelted before I visited the region. The character of the ores, their modes of occurrence, and their associations are similar to those of the Queen of Bronze mine.

Some distance northeast of the Queen of Bronze mine is a prospect on which considerable work has been done and some good ore has been found.

The Elder Mining & Smelting Co. has recently been active in that region, producing copper in 1912, when some raw ore was shipped to Kennett for smelting.

REYNOLDS MINE (115).

A prospect near Rough and Ready Creek, about 12 miles northwest of Waldo, with 850 feet of tunnels, lies in the midst of the great serpentine area and has attracted the attention of prospectors for copper. I was unable to visit the prospect, but Mr. Reynolds kindly sent me at my request a series of samples to illustrate the ores of his prospect. The material is much altered and weathered serpentine, stained green by carbonate of copper, together with delicate pinkish or bluish gray tints, suggesting the presence of cobalt. Some pyrrhotite seems to be present, but it is evident that the samples are so altered that they afford an unreliable basis for judging the ores. Both nickel and cobalt have been reported in these ores. Tests by Chase Palmer in the chemical laboratory of the Geological Survey showed the presence of 0.29 per cent nickel, but no cobalt was found.

CHETCO COPPER CO. MINE (101).

The same serpentine belt with which the copper deposits are associated on Fall and Rancherie creeks extends southwest by the head of Canyon Creek to Chetco River, where a number of similar deposits occur and have been prospected, by the Chetco Copper Co. and others, by tunnels aggregating more than 250 feet. The ore appears to be mainly chalcopyrite, but Dixon's prospect has furnished some native copper and some remarkably beautiful specimens of the bright red oxide of copper, cuprite, in minute cubic crystals. A small amount of ore is said to have been shipped from this locality.

UNITED COPPER-GOLD MINES CO. MINE. (78).

The United Copper-Gold Mines Co. has a small inoperative mine and furnace on Fall Creek, half a mile above its junction with Illinois River, at an elevation of about 1,400 feet above the sea. The copper ore of this locality attracted attention many years ago, and early in the sixties of the last century a little furnace was erected at the mouth of Rancherie Creek to smelt local ores. The product was packed about 30 miles across the mountains to the coast. Another small furnace was built on Fall Creek in 1894. Both attempts failed, but about 1899 several hundred tons of ore was packed out to Selma, hauled thence to Grants Pass, and shipped to Tacoma, where it is said to have been smelted at a profit. No large ore bodies were found and operations ceased several years ago.

The country rocks of the deposit are greenstone and serpentine. The greenstone is an ancient volcanic mass, a mixture of lava flows and tuffs of Mesozoic age that are greatly altered. Its fragmental character, though not a prominent feature, may be clearly seen on close examination of the clean exposure near the mouth of Fall Creek, where the rock is made up of many lapilli. The serpentine is an altered saxonite, evidently of later eruption than the greenstone with which it is in contact.

The mine is developed by two tunnels connected by a bridge across Fall Creek. The one on the east side is 400 feet in length and that on the west side about 125 feet. At the mouth of the latter there is a winze, from which most of the ore was obtained.

The ore minerals are chalcopyrite and pyrrhotite, generally more or less intermingled, and either may be most abundant. Malachite is rare. In some places the pyrrhotite appears as small streaks in the chalcopyrite. The ore bodies removed were in the serpentine near its contact with the greenstone. It is possible that some ore occurred in the greenstone, but the greater portion, if not all of it, appears to belong to the serpentine. The ore bodies were comparatively small and were in irregular bunches, not in distinct veins. The pyrrhotite was tested for nickel by R. C. Wells in the chemical laboratory of the Geological Survey. A mere trace of nickel was found, possibly 0.001 per cent.

CALUMET MINE (77).

Bodies of pyrrhotite and chalcopyrite reported to contain gold, like those in the mine previously described, occur on the border of the same mass of serpentine on Illinois River, near the mouth of Fall Creek and a short distance farther west along the slopes of Rancherie Creek in the Calumet mine. As far as seen, and they are fairly well exposed in the banks of the streams and in the open cuts and tunnels of the mine, the ore bodies are small and though near the contact of serpentine and greenstone are generally in the greenstone. The greenstone is tuffaceous, and at several points near the contact, especially on the spur between the forks of Rancherie Creek, it contains traces of oolitic limestone.

There can be no doubt concerning the presence of copper and iron in the chalcopyrite and pyrrhotite, but the presence of nickel is always an important question. Two specimens of pyrrhotite were tested by R. C. Wells, but no nickel was found.

The chief attraction of the Calumet mine is its gold quartz, which is discussed more fully in connection with the mines of that metal, on pages 63–64.

COLLIER CREEK PROSPECT.

The copper ore on Collier Creek, exploited for a number of years, is said to occur like that of Fall Creek, in bunches in serpentine. The

specimens from Collier Creek I have seen at various places were chiefly cuprite, the bright red oxide of copper, and suggest the existence of a considerable body of oxidized ore.

THOMPSON MINE.

Mention should be made of the copper ore that has been found in a mineralized belt nearly 25 miles to the northeast in the vicinity of Mount Bolivar, the most prominent peak in the greenstone belt that is shown near the northwest corner of the map. The greenstone of this belt is impregnated at a number of places by pyrite, chalcopyrite, and bornite, and contains numerous veins of quartz and calcite. The most important copper prospect noted in this region is on the west fork of Cow Creek at the locality known as the Thompson mine. It has been exploited by several tunnels and inclines and yielded at least 50 tons of ore, chiefly chalcopyrite and bornite. The works were closed at the time of my examination, but the occurrence of so much ore on the dumps apparently shows the existence of ore bodies of considerable size. This prospect, although only 17 miles from the main line of the Southern Pacific Railroad at West Fork and all down grade, is reached by trail only. Numerous prospects have been opened in this mineralized belt between Mount Bolivar and Rogue River, but none of greater promise than that already noted has yet been found.

GREEN MOUNTAIN COPPER PROSPECT.

Northeast of Galice the Green Mountain Copper Co. has recently opened up a suggestive mass of pyritic ore at an elevation of 3,900 feet on the northwest slope of Green Mountain, 15 miles east of Glendale and about a mile from the country road. The company controls 330 acres of land, part of which is patented.

The country rock is typical greenstone that has been greatly sheared and altered but still preserves its original structure and composition sufficiently to show its diabasic character. The greenstone belt, nearly a mile wide over the summit of Green Mountain, lies between belts of slates and other sedimentary rocks and is cut off a short distance to the south by serpentine, whose intrusion has influenced the mineralization of the region.

The ore impregnates the greenstone and forms lenses. It is usually incased in deep-green chloritic material.

The important copper mineral is chalcopyrite, which is intermingled with a large proportion of pyrrhotite and pyrite. The range of color from bronze to brass-yellow suggests the presence of cubanite, but the ore tested that was free from chalcopyrite gave no trace of copper.

The outcrop lies in the upper drainage of Starveout Creek, whose placers have been remarkably productive. At the time of my visit

(Sept. 6, 1911) the irregular incline, about 40 feet in length, exposed a body of ore 2½ to 3 feet in thickness, where it disappears beneath the incline. A tunnel is now being run in the hope of finding this ore body at a depth of 200 feet below its outcrop in the incline. The tunnel is already 40 feet in and several hundred feet have yet to be driven. The Pacific Outlook, of December 28, 1911, reported that the tunnel was in 140 feet and that a 2-stamp mill had just been completed.

COPPER PROSPECTS OF THE RIDDLES QUADRANGLE.

The copper prospects of the Riddles quadrangle have attracted attention for a number of years. In 1907 Prof. G. F. Kay examined the prospects known as the Joseph Ball mine and the Oak mine. He describes them as follows: [1]

> The Joseph Ball mine is situated in the NW. ¼ sec. 36, T. 32 S., R. 4 W., which is on the southwest slope of Cedar Springs Mountain. The elevation at the mine is about 4,250 feet. Some ore has been carried by pack train to Glendale, on the Southern Pacific Railroad, a distance of more than 20 miles. The country rock is serpentine, which has been greatly fractured and sheared, and locally, where it has been decomposed, magnesite with some strontianite is present. The ores consist of native copper, copper glance, cuprite, and the copper carbonates. They are in a faulted zone in the serpentine, which shows numerous slickensided surfaces on which are vertical striæ. Within the workings the faulted zone varies in direction and the plane of shearing is very irregular. On this plane have been found flat pieces of native copper as large as the hand; the copper glance and cuprite have also been found on this plane as nodular masses and as scattered fragments. The workings consist of an upper tunnel of 150 feet along the fault zone and a lower tunnel of 145 feet from which there is an upraise of 60 feet to the upper tunnel. At the time the mine was examined the company was preparing to sink, from the lower tunnel, a shaft on the fault plane.
>
> The Oak mine, in the SW. ¼ sec. 4, T. 35 S., R. 5 W., was located in 1905. It is owned by the Oak Consolidated Mining & Milling Co. Copper was found on this property while a gold-quartz vein was being developed. A tunnel was being run to crosscut some quartz stringers in a fractured zone, when copper pyrites were found. The mineral occurs as small irregular masses in a fractured and chloritized greenstone. During the summer of 1907 the company was installing an air compressor, hoists, and machine drills, and plans were being made to prospect the property thoroughly.
>
> Some prospects of copper occur in greenstone near Glendale, and A. D. Leroy, of Merlin, has done some work on a quartz vein carrying copper in the N. ½ sec. 8, T. 35 S., R. 6 W.

The Rowley copper prospect is situated about 10 miles northeast of Green Mountain, in essentially the same belt, on Drew Creek, 8 miles from Drew and 15 miles by wagon road to Trail. The property consists of 10 claims, covering, it is said, two veins about 500 feet apart. The country rock is reported to be slates and diorite, but the ore samples show traces of mica schist, such as results in many places from the contact metamorphism adjoining the borders of

[1] U. S. Geol. Survey Bull. 340, p. 152, 1908.

granodiorite, and suggests the presence of such a contact in that region, for along the eastern border of the Riddles quadrangle, a few miles west of the Rowley prospect, there are large masses of greenstone and granodiorite which extend to the northeast.

The ore is chiefly pyrrhotite, chalcopyrite, and chrysocolla, with some malachite and a larger proportion of gangue quartz. The ore is said to occur in streaks 10 to 30 feet wide, running 3 to 4 per cent copper and $2 to $3 in gold, with as much silver. There are a number of open cuts and shallow shafts and about 180 feet of tunnels.

In 1912 the mine production of copper in Oregon was 260,429 pounds, valued at $42,971, an increase over the production of 1911 of 167,293 pounds in quantity and of $31,329 in value. Of the copper produced in Oregon in 1912, that from Josephine County was valued at $41,973 and that from Lane County at $841.

No lead was produced in Oregon in 1911, but in 1912 two mines, one in Jackson County and one in Lane County, yielded 39,317 pounds, valued at $1,766.

PLACER MINES.

AURIFEROUS GRAVELS (CONGLOMERATES) OF CRETACEOUS AGE.

GENERAL CHARACTER.

Besides the stream gravels of fluviatile origin referred to under the description of the three cycles of erosion (p. 13) there are in southwest Oregon, as well as in northwest California, a number of important deposits of older gravels, now conglomerates, Cretaceous in age and of marine origin.

These auriferous conglomerates in California were first described by R. L. Dunn [1] and later by H. W. Turner,[2] who recognized their marine origin. They are shore deposits about a Cretaceous island, the Siskiyou Island of Condon,[3] whose approximate outline when the beach gravels, now conglomerate, were formed is shown in figure 9.

During the Cretaceous period the island gradually subsided until it was almost if not completely covered by the sea. Among the later as well as the younger gravels of Trinity River above Weaverville are found pebbles of fossiliferous Cretaceous sediments which evidently came from the high mountains about the river's head, affording positive evidence of Cretaceous submergence.

This Cretaceous cover, now almost completely washed away, was derived from the auriferous slate bedrock series of the Klamath Mountains and probably contained gold at many localities. By its

[1] Dunn, R. L., California State Mineralogist Twelfth Rept., pp. 459-471, 1894.
[2] Turner, H. W., Eng. and Min. Jour., vol. 76, pp. 653-654, 1903.
[3] Condon, Thomas, The two islands and what came of them, 1902. Revised and enlarged by Ellen Condon McCornack in 1910 as "Oregon geology." See also Watson, C. B., Prehistoric Siskiyou Island and Marble halls of Oregon.

disintegration and erosion the gold was liberated and concentrated in later gravels. This concentration appears particularly marked along the old coast line. The rich placers (indicated by ×) along this old coast, line both southwest and northeast of Redding, Cal., as well as in the neighborhood of Yreka and in the Cottonwood mining district near the Oregon line, probably owe much of their richness to

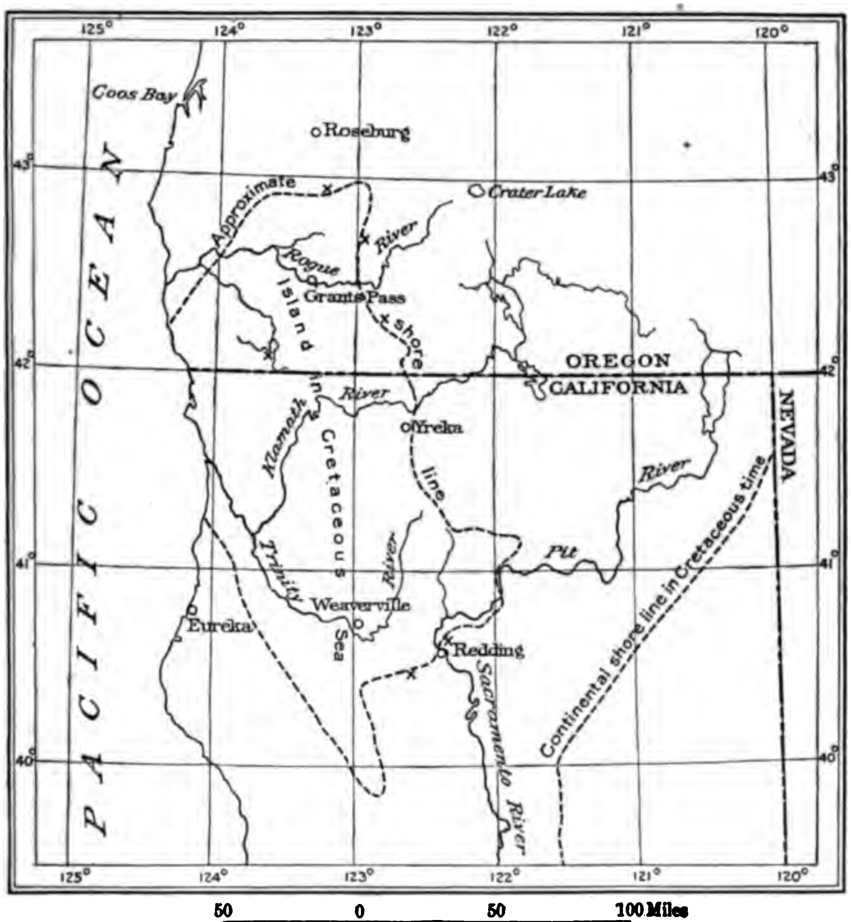


FIGURE 9.—An approximate shore line of Cretaceous islands when auriferous gravel beaches were formed. ×, Auriferous gravel prospects in Cretaceous conglomerate.

the auriferous basal conglomerate of the Cretaceous. In Oregon mines apparently thus enriched are located near Ashland, on the head of Graves Creek, to a small extent in the Canyonville region, and more especially in the neighborhood of Waldo.

COTTONWOOD DISTRICT, CALIFORNIA.

This locality early attracted attention, and in the literature already referred to has been more fully described than any other occurrence

seamed in an intricate manner by secondary silica, which is usually white and more or less crystalline, though stained in many places with iron oxide. Along the ridge crest these pre-Cretaceous rocks contain some small veins and stringers of quartz, more or less filled with pyrite and containing a little gold and other metals or their compounds. In many places prospecting has been done along the ridge and some small auriferous veins have been found, though none of sufficient size and value to warrant mining. Formerly these rocks were classed indiscriminately as belonging to the "auriferous slate series," and obviously they are to a small extent auriferous and have been the source of the gold and other metalliferous compounds found in mining. Presumably all the gold in the various deposits herein described was derived from the veins, seams, or pockets that existed in the eroded portions of these rocks.

Cretaceous rocks surround the northern end of the ridge and cover all of its lower flanks. In the placer workings on the eastern slope of the ridge only Cretaceous rocks have been uncovered and the bedrock is composed of clay shales and sandstones, whereas on the opposite side shales, sandstones, and conglomerates of Cretaceous age are exposed and below them the older complex mentioned above.

The conglomerates are generally very coarse, as shown in Plate VII, and are composed of rocks found in the underlying complex. Many of the bowlders and pebbles are only slightly rounded or subangular, and when exposed to the weather they readily separate and fall to pieces, the sandy matrix crumbling to sand and clay. The shales are yellowish concretionary clay shales that quickly pass into clay when exposed to the weather. They are thinly stratified and generally unfossiliferous.

A thin layer of very fossiliferous sandstone is present above the shales in many places in the old placers on the northwest slope of the ridge. This is the locality from which many of the Cretaceous fossils were obtained that were described or listed in Anderson's paper on the Cretaceous deposits of the Pacific coast.[1] Both the concretions and sandy layers connected with the shales carry the fossils found in these beds.

Post-Cretaceous erosion has broken up the sandstone into blocks and irregular bowlders, which are left in some confusion, though a little search readily reveals their place of origin. As the position of the mines is along the extreme edge of the Cretaceous, naturally the thickness of these beds is variable in the vicinity of the old workings.

On the northern side of the ridge the conglomerates are locally from 15 to 35 feet thick, and the shales do not exceed a few hundred feet. Both conglomerates and shales thin out toward their borders to a

[1] Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., vol. 2, No. 1, 1902.

CRETACEOUS CONGLOMERATE IN FORTY-NINE MINE, NEAR PHOENIX, OREG.

thickness of only a few feet. Their thickness in the opposite direction can not be readily told from the exposures.

The Cretaceous conglomerates of this locality have long been known to carry gold, and in the past have been mined as a part of the auriferous deposits. Excavations made into the conglomerate by hydraulic mining since 1895 are shown in Plate VII.

The quantity of gold contained in these conglomerates was not very great, probably not exceeding 60 cents a cubic yard, but as the conglomerate was not very hard, and also tended to disintegrate on exposure, the surface uncovered each year could always be mined economically during the following season, and this was done in connection with other mining.

No other method of working than ordinary hydraulic mining was ever attempted on these conglomerates, as they were not considered rich enough to warrant crushing by stamp mills.

The extent of the deposits that are rich enough to be mined economically by any process is unknown and may in fact be confined to the pre-Cretaceous drainage lines of this vicinity. Very probably these auriferous conglomerates have contributed to the enrichment of the overlying alluvial gravels under the conditions of their formation. No doubt if large areas of this conglomerate were uncovered and exposed to the weather its natural disintegration would render it minable to some extent, or if they were sufficiently explored it is not unlikely that some portions would be found rich enough to be reduced profitably by improved methods.

The practical abandonment of the Forty-Nine mines was partly due to objections raised as to the disposition of the débris, and partly on account of the increased value of the water for other purposes than mining.

CRETACEOUS CONGLOMERATE OF WALDO.

GENERAL CHARACTER.

Nearly 4 miles north of Waldo, on the drainage ditch from the Logan mine to Illinois River, a series of fossiliferous sandstones and conglomerates of Cretaceous age are well exposed. In the deep cut tailrace from the north end of the mine these tilted sandstones, with some shales and conglomerate (*a*, fig. 11), are clearly overlain by a horizontal sheet of gravels (*b*, fig. 11) which form the great alluvial plain of that portion of the valley of Illinois River and Sucker Creek.

In the accompanying section across the Logan mine, figure 12, the relations of the basal conglomerate of the Cretaceous are clearly seen. It forms, at least in part, the bedrock of the mine in which the overlying new gravels of the third cycle have been worked. The somewhat rotten reddish conglomerate is composed chiefly of well-rounded greenstone pebbles and bowlders, with some of granitic

rocks. It is nearly 100 feet thick and dips 35° W. conformably beneath fossiliferous Cretaceous sandstones, so that its age is evident.

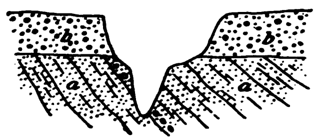


FIGURE 11.—Section of tailrace of Logan mine. *a*, Cretaceous sandstones, shale, and conglomerate; *b*, gravels of third cycle of erosion.

The same soft conglomerate lies at the bottom of the new portion of the Logan mine, only about a mile north of Waldo, and also of the Deep Gravel mine, nearly a mile northwest of Waldo, but although the gold is found in all three mines chiefly in the overlying much later gravels, it is said that in each place some gold occurs in the basal conglomerate itself.

From the Logan and Deep Gravel mines the basal Cretaceous conglomerate rises to the south. In the immediate vicinity of Waldo it has been washed away, but a mass of it still clings on the crest of the spur nearly a mile south of Waldo, at the Osgood mine, generally known as the High Gravel mine.

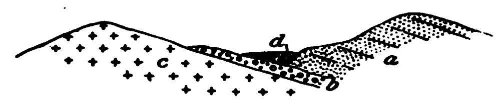


FIGURE 12.—Cross section of Logan mine, 3½ miles north of Waldo. *a*, Cretaceous sandstone, fossiliferous; *b*, basal Cretaceous conglomerate (auriferous); *c*, serpentine; *d*, later auriferous gravels forming valley plain.

As the gravel at the High Gravel mine is wholly Cretaceous, the mine will be described in this place, but the Logan and Deep Gravel mines will be described under the gravels of the third cycle. (See pp. 119–120.)

HIGH GRAVEL (OSGOOD) MINE.[1]

The High Gravel mine is about 1 mile south of Waldo, on a ridge, which forms the divide between the east and west forks of Illinois River. The summit of the ridge is about 1 mile from the east fork and is more than 300 feet above it. The chief workings are at the head of Allen Gulch, on the east slope of the ridge. The most recent workings, however, are on the west slope of the ridge. Of the summit of the ridge a width of only about 100 feet remains to be mined. * * *

The deposits mined on the west slope run parallel to the ridge. They are more than one-eighth of a mile in length and have an average width of about 100 feet. The conglomerates do not extend down the slope, but constitute only a remnant, which here has escaped erosion, as is true of other areas of conglomerate in the region. No conglomerate remains on the summit of the ridge a short distance to the north of the present mine pit. The surfaces on which the conglomerates were laid down were uneven, and hence the thicknesses of the conglomerates vary. The maximum thickness exposed is more than 60 feet. The conglomerates have a purplish tint. They are not strongly cemented, and the bowlders are rather uniformly distributed throughout the section. Much of the material is less than 1 foot in diameter; a few bowlders are more than 3 feet. Distinct joints are present in the conglomerates, and a few small veinlets occur. The bedrock is a fractured, fissured, decomposed, and veined greenstone, which, owing to the presence of iron oxides, has a decidedly purplish tint.

The workings on the east side of the ridge extend down Allen Gulch to the east fork of Illinois River, but only those gravels which are near the summit of the ridge are of

[1] Kay, G. F., U. S. Geol. Survey Bull. 380, p. 72, 1909.

Cretaceous age. These conglomerates extend along the ridge in a north-south direction. At the south end of the workings they are more than 50 feet in thickness; at the north end and close to the summit of the ridge they are only a few feet thick; and a little farther on they have been completely eroded. The best values are said to be near the bedrock, but some gold is found higher up in the deposit.

These Cretaceous conglomerates are shore deposits, derived from older rocks similar to those on which they now lie. As stringers carrying values are fairly widespread in these old rocks, some gold is probably present in much of the conglomerate which has been derived from them. But whether or not these values are sufficiently concentrated, as at the High Gravel mine, to be profitably mined can be determined only by prospecting.

AURIFEROUS GRAVELS OF THE FIRST CYCLE OF EROSION (KLAMATH PENEPLAIN).

Age of the Klamath peneplain.—The attitude of the auriferous conglomerate and sandstones along the shore line of the Cretaceous island is such that for the most part they dip away from the shore line, generally at a small angle but in some places at an angle as great as 45°, indicating that there has been an important but irregular differential uplift within the Klamath Mountains since the deposition of the auriferous Cretaceous conglomerate. This deformation, taken in connection with the lack of definite association between the auriferous conglomerate and the Klamath peneplain, is evidence that the Klamath peneplain, although in course of development, was not completed during the Cretaceous, but during a later epoch.

The Eocene strata at the north border of the Klamath Mountains are almost wholly shales and sandstones, such as are derived from the residual mantle of a land with gentle slopes. The succession of coal beds with alternating fresh-water and marine shells through a great thickness of Eocene strata is proof not only of a gentle oscillation of the land, but also of a predominant gradual subsidence of the land during the Eocene and transgression of the sea over the lowlands. These lowlands overlapped by the sea were largely developed during the Eocene, and the plain probably reached its greatest development during the later portion of the Eocene or early Miocene, when the Klamath Mountains were wholly a land area eroded to low relief near sea level, practically a peneplain, and the auriferous gravel was accumulated in the channels of the first cycle.

Situation of the gravel beds.—Two masses of more or less auriferous ancient stream gravels lie practically in the Klamath peneplain and apparently belong, without question, to the first cycle—that is, the Klamath peneplain cycle. These masses are comparatively small and lie at an altitude of 4,000 feet. They are only 7 miles apart and occur northwest to north-northwest of Kerby, the one on the southern limb of Gold Basin and the other just east of York Butte. (See Pl. VIII.) In both places the course of the depositing stream was northwest approximately parallel to Illinois River.

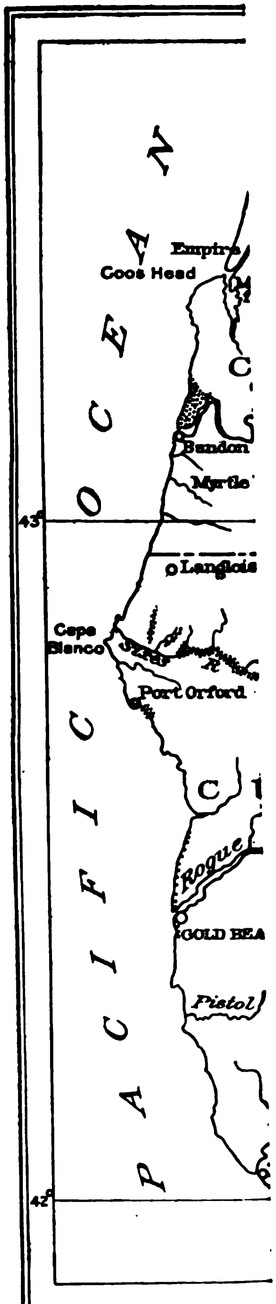
Gravels of Gold Basin.—About the head of Tin Cup Creek, 15 miles northwest of Kerby, there is a V-shaped remnant of the Klamath peneplain known as Gold Basin on a large mass of granodiorite. The apex of the V points east, and across its southern arm is a broad, shallow valley filled by an old stream bed running approximately N. 20° W. The surface plain of the stream bed is more than 1,000 feet in width and 2,000 feet in length and is limited at both ends by deep, rugged canyons. The gravel has a thickness of 110 feet where best exposed on the steep southern slope. Near the bottom the gravel, though somewhat decomposed, is more or less firmly cemented, and this condition extends throughout the mass. It has been tunneled on bedrock for 30 feet. The material is generally coarse, mostly cobblestones up to bowlders 4½ feet in diameter mixed with pebbles and sand. There are no layers of sand to afford definite evidence of stratification. The pebbles are well rounded and are for the most part composed of basic eruptive rocks, greenstone, gabbro, peridotite, and pyroxenite, with some of granite. Though generally greenish, they are in places colored reddish by a surface deposit of oxide of iron. The top portion of the deposit is finer, with some fine gravel capped by a reddish soil. Wherever I saw the pebbles in place the course of the stream was not clearly indicated by their position, though they appear to be inclined southward, and it is believed that the stream came from that direction. The gravel was tested in 1875 or 1876 by sinking a shaft (now filled with water within 20 feet of the surface) and found to contain very little gold. Most that was found is said to have been in the fine material of the surface.

The only available water is snow water, which is obtainable only in small amount during a short season. It is gathered by a mile or more of ditch, but reaches the mine with scarcely 15 feet of head, and only a small amount of gravel was mined before work was suspended.

Gravel near York Butte.—York Butte is 17 miles directly northwest of Kerby and nearly 7 miles north-northeast of Gold Basin. It lies at the river end of a prominent flat-topped divide between Silver Creek and Red Dog, a branch of Briggs Creek, but is separated from the flat portion of the divide by a gap partly filled with stream gravel, as shown in figure 13.

The gravel terrace clinging to the northeast side of the gap has a width of nearly 700 feet and a length of more than 1,200 feet in a direction N. 20° W., parallel to the general course of Illinois River.

The gravel plain is ended abruptly by steep slopes which show the gravel to be about 100 feet in thickness. Most of the gravel is coarse, the deposit containing in some places many well-rounded to subangular bowlders up to 3 feet in diameter. The pebbles are generally less than 4 inches in diameter, and near the top finer material becomes most abundant.



Base from Post Route map

Gravels of fi

MAP SHOWING DISTI

The bowlders and cobblestones are largely greenstone, but on the surface quartz pebbles are common. An uprooted tree exposes much fine material containing particles of kaolin, as if the sediment were derived from a residual mantle of a country of low relief. In the surface exposures as far as seen the gravel was not cemented. No shafts or open prospect cuts were found to determine how much, if

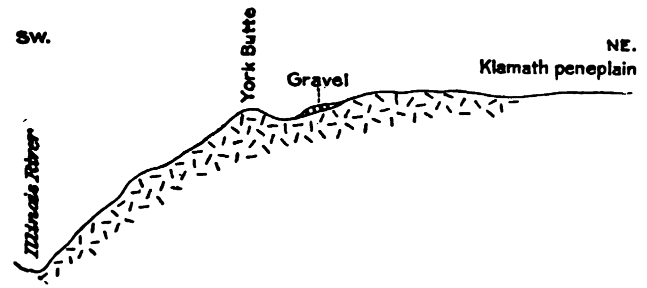


FIGURE 13.—Section showing relations of gravel of York Butte.

any, of the gravel is cemented. The mass of the gravel is of the same character and age as that of Gold Basin, and like it is probably more or less firmly cemented.

AURIFEROUS GRAVELS OF THE SECOND CYCLE OF EROSION.

Location and character.—The gravels of the second cycle are more extensive and of much greater economic importance than those of the first cycle. All the gravels of the second cycle thus far recognized appear to have been deposited by the same stream. They occur near Galice Creek and Briggs Creek and are roughly outlined on the map (Pl. VIII) for a distance of 18 miles. The best exposures are in the Old Channel diggings as well as the Reed and the Blue Gravel diggings near Galice, where hydraulic mining operations have been carried on for many years.

The two masses near Briggs Creek, regarded as part of the same deposit, are clearly a stream valley filling, although the surface portion is a firmly cemented conglomerate.

The course of the stream was northeast across the divide between Briggs Creek and Taylor Creek to Galice Creek, at a general altitude of about 2,700 feet, the surface sloping toward the northeast from very nearly 3,400 feet on the Briggs Creek side to about 1,600 feet at the Old Channel diggings near Galice. These gravels are in general nearly 2,000 feet below the level of the Klamath peneplain and from 700 to 2,500 feet above the nearest points of Rogue River and Illinois River, between which they lie. The valley occupied by these gravels is broader, with gentler lateral slopes, than the canyons in which the master streams, Rogue and Illinois rivers, now flow, and it may be regarded as belonging to the second cycle of erosion.

Several mining men of large experience in that region report the old channel to extend southwest beyond Briggs Creek to the neighborhood of Waldo, but as already shown the old gravels of the Waldo region, especially those in the Osgood mine and the basal, false bedrock portion of the Logan and Deep Gravel mines, are of Cretaceous age and marine origin and much older than the old-channel gravels between Illinois and Rogue rivers. The latter gravels probably represent an early stage of Illinois River, which turned from its present course just above the mouth of Sixmile Creek and entered Rogue River just below Galice. The gravels of the same epoch in the Kerby and Waldo region may occur with the gravels overlying the Cretaceous conglomerate.

To the northeast these old-channel gravels have not been recognized with certainty beyond Galice, where the stream enters Rogue River.

Attention should be called to the fact that from Galice southwestward to the Briggs Creek meadows the bedrock of the old channel is black slate close to its contact with greenstone, a contact which is the general horizon of the Big Yank lode, and it may well be that some of the gold is derived from this horizon, although it seems more probable that most of it came from the adjacent igneous rocks which lie northwest of the slates and form the bedrock of the old channel beyond the Briggs Creek meadows.

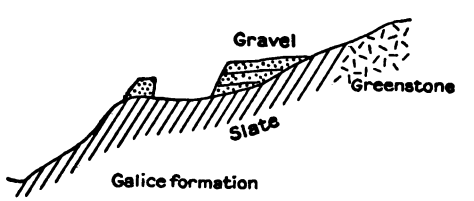


FIGURE 14.—Section of Old Channel mine at Home Place.

Old-channel gravel near Galice Creek.—The property of the Old Channel Mining Co., purchased by the Old Channel Hydraulic Mining Co., and lately controlled by G. E. Sanders, embraces a large tract on a gravel terrace one-fourth to two-thirds of a mile in width and nearly 2½ miles in length, parallel to Galice Creek and Rogue River from Blanchard Gulch to Rocky Gulch. The mine was first opened near the southwest end at the Home Place, Reed diggings, and Blue Gravel diggings, but later at the northeast end on Rich Gulch, where it has been worked chiefly ever since.

The main ditch from Galice Creek and its tributaries is said to supply 5,000 miner's inches of water with a head of about 350 feet during the rainy season, but during the dry season the supply drops to 300 miner's inches, and work ceases.

At the Home Place the section shown in figure 14 illustrates the general relations of the gravel to bedrock and to Galice Creek, which occupies the valley at the left.

The gravel terrace about 600 feet above Galice Creek has an altitude of 1,515 feet, and the thickness of the gravel is about 115 feet. The section shown in figure 15 is exposed in the bluff at the side of the channel, which has been mined for a width of about 100 yards and a length of nearly a mile. The bedrock is composed throughout of Jurassic black slates and thin-bedded sandstones, only a short distance, however, from the greenstone contact.

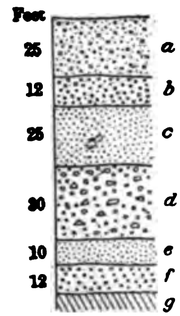


FIGURE 15.—Section of gravel in Old Channel mine at Home Place. *a*, Gravel and sand, pebbles decomposed; *b*, gravel, yellow and white, decomposed; *c*, sand; *d*, gravel, coarse, and some angular bowlders; *e*, sand; *f*, gravel, no bowlders; *g*, slate bedrock.

The gravel is generally without cement, but in some places near the bottom of the channel it is feebly cemented. The pebbles, especially of the beds near the surface, are partly or completely decomposed, being easily cut with a knife, but in the lower beds the pebbles are generally hard and not affected by weathering. The main channel of this portion of the mine has been worked out, and operations on a large scale ceased here some years ago.

The Rich Gulch portion of the Old Channel mine covers a large area on both sides of the gulch, and many acres of gravel ranging in thickness from 15 to 210 feet have been washed away. The gravel terrace, which slopes gently toward Rogue River, has a width of nearly a mile.

The western edge of the gravel plain on the north side of Rich Gulch near the Headquarters has an elevation of about 1,500 feet. The sections of the gravel in different parts of the channel vary widely. At one point on the western edge where mined in the spring of 1911 the section shown in figure 16 was observed.

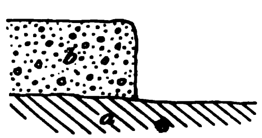


FIGURE 16.—Section on western edge of Old Channel mine, north side of Rich Gulch. Black slate bedrock (*a*), overlain by 80 feet of coarse bowlders, gravel, and sand (*b*).

The entire bluff, about 80 feet in height, exposed coarse, angular, bowldery gravel and sand. It lies close to the north edge of Rich Gulch and appears to belong to the deposit of a lateral stream rather than to that of the main channel.

Several hundred yards east of the exposure shown in figure 16 a bluff about 180 feet in height exposes a section (fig. 17) of the deposits in the main channel. A section on the south side of Rich Gulch is shown in figure 18.

The coarse gravel of the 5-foot bed at the bottom in both sections is well rounded and composed largely of greenstone with considerable quartz. Cobblestones as large as 8 inches in diameter are common. North of Rich Gulch bowlders are numerous, but on the south side bowlders are few, and the gravel is quite firmly cemented. This

coarse bottom layer of gravel and bowlders is limited to the main channel and contains most of the gold, although some gold is said to be distributed throughout the great thickness of overlying fine gravel and sand.

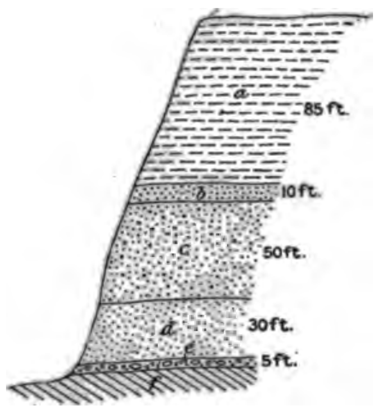


FIGURE 17.—Section of gravel in Old Channel mine, north of Rich Gulch. *a*, Red earth and clay; *b*, gray sand; *c*, gravel and sand; *d*, fine gravel; *e*, bowlder bed and coarse gravel; *f*, slate bedrock.

The gold is generally fine, but some of it is coarse. The largest nugget reported weighed 2½ ounces. A large body of available gravel lies south of Rich Gulch, where most of the recent work has been carried on.

The stratification of the gravels as far as observed is horizontal and apparently undisturbed, but the abrupt changes in the level of the bedrock along lines transverse to the course of the old channel suggest faulting.

The bedrock is chiefly slate with some sandstone, but near the western border of the mine north of Rich Gulch the slates are cut by dikes, and both rocks are affected by a small fault that strikes N. 80° W. and dips 72° SW. The relation of this fault to the gravel could not be determined. A profile of the bedrock in the main channel, as shown in figure 19, includes two parallel faults, which are suggested by the different bedrock levels and bluffs in the course of the main channel. These faults were not actually seen, but the small fault referred to above and well exposed in the slates proves the existence of such features and affords the most rational explanation of the facts.

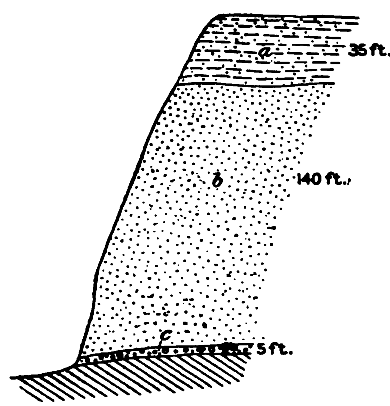


FIGURE 18.—Section of gravel in Old Channel mine, south of Rich Gulch. *a*, Clay and sand; *b*, fine gravel, well rounded; *c*, coarse gravel, containing cobbles as large as 8 inches in diameter but few bowlders.

Concerning this matter Mr. J. R. Harvey, of Grants Pass, who has worked the Old Channel mine, remarks in a letter dated April 24, 1912:

> Your cross section at the Old Channel mine showing Rich Gulch and a fault to the northeast in the bedrock is, in my mind, without question a fault, as could easily be seen when we were working the ground. The part of the bedrock marked *b* is raised 30 or 40 feet higher than its proper place. The bedrock at *a* and *c* is in the regular

grade with the bedrock in the openings on the Home Place and Blue Gravel and the flat north of Rocky Gulch. There is also a small fault a mile and a half south, near Blanchard Gulch, where the fault in the gravel can easily be seen, with a very distinct gouge in the slip of 4 to 6 inches wide.

In the southern portion of the Klamath Mountains the gravels of this epoch have been faulted to a marked degree, but in the old channel deposit of the Galice-Kerby region of Oregon the only faults observed were the small ones noted above.

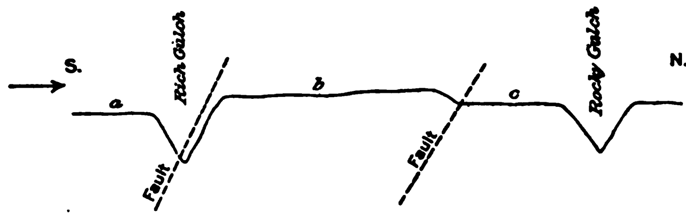


FIGURE 19.—Profile of old-channel bedrock in Harvey mine. Arrow shows course of ancient stream. Bedrock at *a* is 30 feet lower than that at *b*, whereas at *c* bedrock is 15 feet lower than that at *b*.

The southwest portion of the Galice Creek body of the old-channel gravel deposits is well exposed in the Blue Gravel diggings 700 feet above the stream on the terrace between the forks of Galice Creek. At this point the gravel is from 100 to 140 feet thick. Although the gravel is generally fine and carries decomposed pebbles, there is at the bottom, as in the Harvey mine, a 5-foot bed of fresher gravel with some bowlders. About 2 acres of gravel have been washed away, but much was left on the sides of the channel years ago when the work ceased.

Old-channel gravels near Briggs Creek.—The Column Rock mass of old-channel cemented gravel caps the terrace on the end of the divide between Swede Creek and Onion Creek at an elevation of about 3,400 feet above the sea and 1,500 feet above Briggs Creek. Its area is roughly estimated at 10 acres. On the steep slope toward Briggs Creek the section, 180 feet in thickness, shown in figure 20 is exposed.

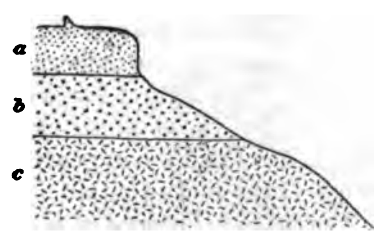


FIGURE 20.—Section of old-channel deposit at Column Rock. *a*, Cemented gravel; *b*, coarse gravel; *c*, greenstone.

The upper layer of gravel, about 80 feet in thickness, is firmly cemented and forms a prominent bluff. From its top rises a column of conglomerate that forms a picturesque feature of the region. The pebbles of the upper layer are generally greenstone, subangular, and less than an inch in diameter. Some layers show that the stratification is horizontal and limited to the shallow valley of gentle slopes cut in the greenstone bedrock by the ancient stream.

The lower 100 feet of the deposit is coarse gravel so feebly cemented that it does not form ledges on the gravel-covered slope below the bluff. It contains many cobblestones 6 to 8 inches in diameter, which are well rounded, fresh and smooth, without signs of weathering. There are some greenstone bowlders, especially near the bottom, the largest ones being 4 feet in diameter. No prospects were seen in this body of gravel, but from its relation to McDow's placer mine on Onion Creek it is believed to have furnished some coarse gold for certain ravines of which it forms the head.

South of Column Rock and east of Horse Mountain, in a low gap, the old channel crosses the divide between Swede Creek and Soldier Creek. As seen from Column Rock the horizontal beds of conglomerate form bold bluffs, but the bottom of the deposit is not well exposed. The gravel in the conglomerate bluffs is angular and few of the pebbles are as large as 4 inches in diameter.

To judge from the topography, the old channel probably occurs in the upper drainage of Soldiers Creek, crossing by a low divide to Sixmile Creek and a high gravel bench on Illinois River above Shades ranch. If this view is correct, the old channel might be expected to contribute some gold to the later gravels of Soldier Creek and Sixmile Creek, but as far as I could see there is only a small amount of placer mining on these streams.

AURIFEROUS GRAVELS OF THE THIRD CYCLE OF EROSION.

GENERAL FEATURES.

The auriferous gravels of the third cycle embrace all those that are closely related to the modern streams, along which they form terraces or bars. The highest terraces are about 500 feet above their parent streams, but those mined most extensively lie within 100 feet of the stream level and are in general confined to streams that drain regions in which the rocks contain auriferous quartz veins.

The principal groups of placers of the third cycle in southwest Oregon may be considered under the following heads: The Sixes River and Johnson Creek region, in Curry and Coos counties; the South Fork of the Umpqua and its most important tributary, Cow Creek, in Douglas County; Rogue River and its tributaries, in Jackson and Josephine counties; and, finally, the beach mines of Curry County.

PLACERS OF SIXES RIVER AND JOHNSON CREEK.

Sixes River and Johnson Creek drain the small gold belt extending east and west from Coos County into Curry County, in the neighborhood of Salmon Mountain and Rusty Butte. The South Fork of

Sixes River heads at Rusty Butte. Its bed and the terraces that rise about 50 feet from the stream have nearly all been sluiced off to a point within a few miles of the coast, where owing to the recent landslides the stream is overburdened and placers end.

The Salmon Mountain mine, a well-known placer near the divide between Sixes River and Johnson Creek, is exceptional. It occurs on a spur and is not an ordinary stream deposit but residual material, largely of volcanic products mingled with the auriferous quartz from the degradation of the Mesozoic slates and greenstones of Salmon Mountain.

On Johnson Creek, in Coos County, at the eastern end of the Sixes mineral belt, there are still a few placer mines, notwithstanding the fact that recent landslides have loaded the stream with gravel.

PLACERS OF THE UMPQUA AND ITS TRIBUTARIES.

On portions of the South Fork of the Umpqua and its tributaries, especially Olalla Creek, Myrtle Creek, Cow Creek, and Coffee Creek, there are auriferous gravels of considerable importance.

One of the branches of Olalla Creek traverses a mass of Jurassic slates that have been much intruded by greenstones and furnished considerable bodies of auriferous gravel. On Myrtle Creek, near Nugget, the granular greenstone by its disintegration has furnished residual material and stream gravel that has been mined more or less actively for a number of years. The same is true of gravel on the upper course of the South Fork of the Umpqua, about Coffee Creek, and in places along the course of Cow Creek, whose middle portion is in a rugged canyon.

Starvout Creek, near Booth, is a tributary of upper Cow Creek that drains the northwest slope of Green Mountain, where the Green Mountain Copper Co. (see p. 86) is prospecting. Several small placers on Starvout have been irregularly active for a long time. A large tract has been covered by these placers near the present stream level. Their reputed richness in the early days has stimulated search for the source of the gold.

In Cow Creek canyon below Glendale high gravel benches have been extensively mined. The Victory and Gold Flat, about 7 miles from Glendale, are on terraces about 150 feet above the stream, and the Cracker Jack and Cain mines, a dozen miles farther down the canyon, are on terraces more than 500 feet above Cow Creek.

Among the hills on the valley border between Riddles and Canyonville there are a number of small mines which appear to derive at least part of their gold from the decomposition of the Cretaceous beds on which they rest.

PLACERS OF ROGUE RIVER AND ITS TRIBUTARIES.

WOLF CREEK DISTRICT.

On Wolf Creek and its main tributary, Coyote Creek, there are about half a dozen placer mines, mostly on the gravels near the stream level, but some of them rise to terraces 100 feet above the stream. In Paynes mine, near Foley Gulch, a rusty rotten gravel is well exposed. The greenstone pebbles are completely rotten, though the slate pebbles are not so thoroughly decomposed. This gravel has the aspect of great age, but the illusion is dispelled by the freshness of the dark-gray gravel on which it rests. Coyote Creek has but little fall and the Ruble elevator has been used to advantage. Near the mouth of Bear Gulch Coyote Creek has been mined for nearly half a mile. Its richness is attributed to the fact that it drains the slope from the Martha mine and the west end of the Greenback.

GRAVE CREEK DISTRICT.

Grave Creek, considering its size, is one of the most important placer-mining streams in the State. From Leland to Wolf Creek its valley is traversed by the Southern Pacific Railroad. The richness of its gravels is due to the fact that the stream traverses numerous belts and contacts of Mesozoic slates, greenstones, and serpentine. Almost a score of placers, old and new, occur along its course and about a fifth of them, including the Columbia, which is one of the largest placers in the State, are still active during the good water season.

In ascending the stream from its mouth the first large body of gravel encountered is on a high bench at McNair Flat, for the mining of which a few years ago water was carried in pipes across Cow Creek from the drainage of Mount Reuben.

The Klum property on a bench high above the mouth of Wolf Creek was opened and then abandoned many years ago but was recently worked again.

The Steam Beer mine, owned by H. K. Miller, is near Leland. A ditch 9 miles in length supplies water with 200 feet head. The mine exposes 25 feet of gravel, generally coarse below and made up largely of pebbles of greenstone with scarcely any quartz. The bedrock is Jurassic slate, forming a bench 50 feet above Grave Creek, which affords an excellent dumping ground. For many years until recently the mine has been in operation during the rainy season.

The largest mine on the creek, in fact one of the largest in the State, is the Columbia, near Placer, owned and operated by L. A. Lewis, of Portland. Its water is supplied by two ditches from upper Grave Creek, giving a head of about 100 and 600 feet respectively. The mine occupies the valley of Tom East Creek, which drains the vicinity

of the celebrated Greenback mine, and the mine is advancing in that direction. The gravel ranges from 4 to 50 feet in depth and is coarse below, a few of the bowlders reaching 3 feet in diameter. The fragments are in general subangular and almost wholly greenstone. A few are rotten, but the majority are solid. The gold is fine and nuggets are rare. With three 5-inch giants nearly 6 acres of gravel are mined off annually. The grade is low, and to keep the sluice clear the tailings are washed aside from the end of the sluice box by a powerful side stream.

Above Placer post office for 10 miles Grave Creek cuts a rugged canyon in greenstone, but farther up the country opens out and affords alluvial plains and benches for mining. There are many small mines, generally near stream level, and above Baker Creek the bed of Grave Creek has been extensively washed for 6 miles. The Blalock mine, the most persistent and extensive, is at least in part on a bench 150 feet above Grave Creek and covers over 40 acres.

The occurrence of auriferous Cretaceous conglomerate at several places in the upper part of Grave Creek suggests that some of the gold may be derived from that source.

JUMPOFF JOE DISTRICT.

The lower portion of Jumpoff Joe Creek traverses an area of granodiorite and has no placers, but above the forks placers occur among the greenstone hills on both Jack Creek and the main branch. The principal mine is the Swastika. It occupies a low terrace in the forks at the mouth of Jack Creek The Swastika property is said to include a large part of Jack Creek, and prospects have been made nearly 2 miles above its mouth toward the Daisy quartz mine. The Swastika has been operated by the present company for a number of years. Two 18-inch pipes were used, one with a head of 150 feet and the other of about 75 feet. The sluice dump was disposed of by a strong side stream.

The gravel is 15 to 30 feet deep and is composed of greenstone pebbles. It is coarsest below, the largest bowlders being 2 feet in diameter. In many places the whole mass is rotten, so that many of the bowlders go to pieces under the stream from the giant. The bedrock in the Swastika mine and throughout the slopes of Jack Creek is greenstone.

On the main fork of Jumpoff Joe Creek besides the Sexton mine there are a number of small placers, especially near its head, and a larger one 5 miles below, where Cook & Howland have stripped the shallow bed of the stream, exposing the slates for half a mile to a width of 100 to 200 feet. As the slope is gentle, an elevator was used.

EVANS CREEK DISTRICT.

Pleasant Creek, a branch of Evans Creek, heads against Grave Creek and has several active placers. For over 3 miles the bed of Pleasant Creek was almost completely mined out years ago, and later efforts have been directed to the benches up to 100 feet. The largest amount of work has been done at Harris Gulch, where an area of rotten gravel about 8 acres in extent has lately been removed. A smaller cut has been made in a well-marked terrace at Jamison Gulch, and farther up, between the forks, Thompson Bros. have washed the residual material from a serpentine point 200 feet above the streams.

Lately the Pleasant Creek Gold Dredge Co. and others have been operating near the head of Pleasant Valley. The property in part embraces about 400 acres of placer and dredge land, and 3 miles of new ditch supplies the water.

Nearly all the placers on Pleasant Creek are on granodiorite but are near its contact with both slate and greenstone, which may be the source of the gold. The Pleasant Creek mine, which works the ancient bed by hydraulicking, made the largest output of the mines in Jackson County in 1912.

GOLD HILL DISTRICT.

In the Gold Hill district there are no large placer mines. The most important until within the last few years was the Blockert mine, on Galls Creek. On the same stream work is being done by the hydraulic method on a few other properties. The gravels worked are in the present stream bed. On Sardine Creek also some mining is being done.

It is of interest to note that during the summer of 1908 preparations were being made to mine the deposits south of Kane Creek, in the SW. ¼ sec. 36, T. 36 S., R. 3 W., by means of an electric shovel, dry digging, and passing through washers. The Electric Gold Dredging Co. had already begun work, and the mine has since become one of the most important producers in the State. The electric power shovel used is equipped with three motors, one for hoisting the dipper, one for swinging the crane or boom, and one on the crane or boom for crowding the dipper into the bank. The capacity of the shovel is about 500 cubic yards in 10 hours. The electric power is brought from the Ray dam on Rogue River, 2 miles away. The water used in washing the gravels is obtained from reservoirs on the small stream which flows through the property. The material of the deposit is fine-grained clay and gravel having an average thickness of about 18 feet; very few bowlders are present. The bedrock is slate that has a strike of N. 55° E. and a dip of about 70° SE. The slates have been considerably altered.

FOOTS CREEK DISTRICT.

There are a number of placer mines on Foots Creek and the district is especially noted for its dredges. Of these, the chief producer is the Champlin Electric Gold Dredging Co. mine, located on Foots Creek just below the forks. The other mines are the Black Gold Channel and Cook, on the left fork, and the Lance and Glen Ditch on the right fork.

CHAMPLIN MINE.

The Champlin mine is on Foots Creek, about 2 miles from its junction with Rogue River. It is owned by the Champlin Electric Gold Dredging Co., of Chicago, which bought the property in 1903 from Mr. Lance, of Gold Hill. In the same year the company constructed a bucket dredge equipped with steam power. In November, 1905, electric power from the Ray plant was installed, the cost of mining being thereby reduced one-half. Thirty-six 8-foot buckets are used. They are run at a speed of 7 a minute and the capacity of the dredge is about 2,000 yards a day.

According to Clement H. Mace,[1] the gravel from the buckets is fed to a trommel and the bowlders discharged through this over the side of the boat. The undersized material passes over a set of riffles to a sump or well whence it is elevated by a huge centrifugal pump to the tail riffles in long sluices supported in the center of an auxiliary barge. The major portion of the gold, however, is caught on the boat before reaching the tail sluices.

No gold-saving tables of any kind are used and it is claimed that the gold is all coarse enough to be saved by the Hungarian riffles, though it would seem, according to Mace, that some fine gold is lost.

The average depth of the pay gravel is about 35 feet, but deposits to depths of 46 feet have been mined without reaching bedrock, which is supposed to lie at an average depth of 100 feet. Much of the material is less than 5 inches in diameter, but bowlders of large size are numerous. The best returns are found in a bluish gravel, which is generally reached at a depth of about 12 feet. This gravel is 8 to 18 feet in thickness. Below it is a fine plastic clay, which is difficult to handle and which carries practically no gold. The property contains more than 1,200 acres of placer ground, much of which has been thoroughly prospected and found to carry gold.

As there is too much ground water for shaft sinking the prospecting was done with Keystone drills, and subsequent dredging is said to have given better results than the test holes.

Charles Janin [2] says in his "Review of gold dredging in 1911":

Gold dredging in Oregon has never met with any pronounced success. The total production of gold won from dredging operations in the State does not, so far as can be

[1] Min. and Sci. Press, p. 438, Mar. 23, 1912.

[2] Min. and Sci. Press, p. 101, Jan. 13, 1912.

learned from United States Geological Survey records, exceed $250,000. A number of years ago dredges, both bucket and suction type, were built on the Snake River, and for a while some of them perhaps paid operating expenses.

A company has started to prepare for a dredge this season on ground near Sumpter in eastern Oregon. After considerable prospecting the dredge pit was dug 150 feet square by 12 feet deep, and it is expected the dredge will be built next year. It is to have 9-foot buckets and use electric power furnished by the Olive Lake power plant, and will be the first modern dredge following California methods to be operated in Oregon.

The White-Shelby Hunt dredge, which operated a short time in southern Oregon was originally built for reclamation work at Grays Harbor, Wash. It was afterwards moved to Pleasant Valley, Josephine County, and mounted on wheels. Water interfered with its operation and it was again put on a hull. It was run a short time only; large bowlders and difficult digging proved a serious handicap, and the ladder was broken. The dredge was equipped with buckets of 2 cubic feet capacity and a gasoline engine; it is now idle.

The Josephine dredge, near Waldo, Josephine County, was a 4-foot bucket dredge, using steam and wood fuel, and was owned by an English company. It operated only one season, when it is claimed the company got into litigation. Repairs were not kept up, and while in charge of a watchman the dredge sank and has never been recommissioned. Recently there has been a report of another dredge to be built near Waldo, but no definite information is at hand regarding it.

The only dredge operated in Oregon that seems to have made anything over operating profit, and that could be classed as even partly successful, is that of the Champlin Gold Dredging Co. on Foots Creek, Jackson County. This is an 8-foot dredge operated by electric power. It was operated successfully for several years and during part of the present season, but the bucket-ladder line broke a few weeks ago and the weight of the buckets, about 70 tons, sprang the hull planks and the dredge sank in about 18 feet of water. It is said that repairs will be made at once, the loss being estimated at $35,000.

While this is the only company whose dredging operations have returned a profit in Oregon there seems to be no reason why some of the other dredges should not have proved a financial success if they had been properly designed for the ground on which they were placed. It is probable that investigations will be made in Oregon placers in the near future, and if the proposed dredge near Sumpter returns a profit a number of other dredges of the type that proved such a success in California will be erected. Gold dredging in Oregon produced $34,010 in 1910, according to the United States Geological Survey.

BLACK GOLD CHANNEL MINE.

The Black Gold Channel mine is on the left fork of Foots Creek, in sec. 12, T. 37 S., R. 4 W. It is leased at the present time. In the bank is exposed about 15 feet of unstratified gravels, the coarsest below and containing bowlders, the largest of which are 18 inches in diameter. There is very little fine material. The bowlders, which are almost all of greenstone, are subangular to fairly well rounded. The large bowlders are handled by a derrick. Two giants are used under a head of several hundred feet. The gravels are forced upward for 15 feet over an elevator, but the sluice takes the material 2½ feet above bedrock. The mine pit of the present workings has an area of 1½ acres. A large area down the stream has already been worked over. The bedrock is slate cut by dikes of greenstone. The

strike of the slates is N. 10° E.; distinct joints run about N. 70° W. Numerous small veins are present and have a general northeast-southwest direction.

COOK MINE.

The Cook mine is in the S. ½ sec. 13, T. 37 S., R. 4 W. The pay gravel is in places plainly stratified and consists mainly of fine gravel and clay. The stream bed has been mined for one-fourth of a mile. The bedrock is made up of greenstone and slates cut by numerous greenstone dikes. It has been greatly sheared and faulted. One fault runs N. 75° W. and dips 31° N.; another runs N. 53° E. and has been traced for nearly one-fourth of a mile.

LANCE MINE.

The Lance mine is on the right fork of Foots Creek, in the SE. ¼ sec. 22, T. 37 S., R. 4 W. It is owned by Lance Bros. but is leased at present. The bank has in places a thickness of 20 feet; much of the material is fine. The bedrock consists of lenses of limestone in slates, which are cut by dikes of greenstone. The bed of the stream has been mined for about one-third of a mile, and there is still considerable good ground to be mined.

GLEN DITCH AND OTHER MINES.

The Glen Ditch mine is near the head of the right fork of Foots Creek. It is owned by Boling Bros. The stream bed has been followed for some distance, but much good ground remains to be worked. The gravels are about 15 feet thick.

Other small producers on the right fork are the Mattis & Hausman and the Carr Bros. mines.

JACKSONVILLE DISTRICT.

In the Jacksonville district is the Sterling mine, once the most productive placer mine of southwestern Oregon; also the Old Sturgis, the Spaulding, and the Pearce.

STERLING MINE.

The Sterling mine, owned by the Sterling Mining Co., is located on Sterling Creek, a branch of Little Applegate River, and is about 8 miles from Jacksonville. The property includes about 2,000 acres, extending from a point below the mouth of Sterling Creek to the head of Sterling Creek and over the divide to Griffin Creek. The gravel bank on the west side of the present workings is more than 40 feet in thickness, but on the east side it is only about 20 feet thick. The material consists of gravel and bowlders, the latter being rather uniformly distributed throughout the section. Many of the bowlders are small, but some are more than 2 feet in diameter and a few exceed 8 feet. They are mainly of greenstone.

Much mining has been done on Sterling Creek by the present company. The main stream was mined up from its mouth for more than 3 miles, then a channel east of this stream was followed for about half a mile. Here a channel which is named Bowlder Channel was struck, and this has been followed for about a quarter of a mile to the present workings. The bedrock of these workings is a little higher than the present stream bed and is about 100 yards east of it. The gold is found across a width of nearly 200 feet. It is of medium coarseness and is usually well rounded, although angular nuggets are also present. The average thickness of the gravels in the Bowlder Channel is about 40 feet. It is of interest to note that in these gravels the tusks and jaws of a mammoth, as well as other mammalian bones, have been found. The bedrock at the mine is greenstone in which are patches of slaty tuffs. These rocks have been considerably sheared and veinlets of quartz are present. The strike of the slaty rocks is N. 8° E. and the dip about 60° W. In the present workings is a dike that strikes N. 20° E., containing cross veins which do not extend beyond the dike. The slope of the bedrock is about 2 feet in 100 feet. In 1908 mining was in progress from March until August, during which time about 1 acre was mined. The value of the gravels was about 40 cents to the cubic yard.

The mine is well equipped with ditches, giants, and flumes, the longest ditch being about 27 miles. The water enters this ditch from Little Applegate River about 12 miles above the mouth of Sterling Creek. At the mine the head of the water is now only about 80 feet. A pipe line is being planned to carry water from Squaw Lake to the mine, a distance of 17 miles. The mine has been equipped for hydraulicking for about 30 years. The Sterling Mining Co. was incorporated in 1872. There were issued only 40 shares of stock, which have been held by a very few shareholders. The total production of the mine is said to exceed $3,000,000.

SPAULDING MINE.

The Spaulding mine is on Forest Creek in sec. 4, T. 38 S., R. 3 W. The maximum thickness of the deposit in the present workings is more than 40 feet, but the average thickness does not exceed 25 feet. The lowest 10 feet consists of gravels containing bowlders; the upper part of the deposit is hardpan. Even in the lower part there are but few bowlders, and these are generally less than 1 foot in diameter. They are rounded or subangular and are usually of greenstone, although some are of granodiorite. The mine is equipped for hydraulicking.

OLD STURGIS MINE.

The Old Sturgis mine is on Forest Creek in sec. 10, T. 38 S., R. 3 W. It is now owned by the Sterling Mining Co. The deposit has

an average thickness of about 30 feet; the maximum thickness is about 60 feet. In the lowest 10 feet the gravels and sand contain rounded and subangular bowlders, which are chiefly of greenstone, although some are of granodiorite. The upper part of the deposit is hardpan, which has a reddish to buff color. The gold is fine, and most of it lies near the bottom. The richest ground is said to run as high as $12,000 to the acre. The bedrock is greenstone, much fractured and veined, in places very slaty, the strike being N. 30° E. and the dip 48° SE. In the mine pit the bedrock is about 8 feet above the stream bed and the slope is very gentle. The water supply is sufficient to operate the mine from one to four months each year. The main ditch is about 1½ miles in length. The mine is equipped with giants and a derrick is used for handling the bowlders. About 1 acre a year is mined. From 8 to 12 men are employed. The property contains about 900 acres, a large part of which is placer ground. For many years the mine was owned by the Vance Mining Co.

PEARCE MINE.

The Pearce mine is on the east fork of Forest Creek in sec. 11, T 38 S., R. 3 W. The gravels have an average thickness of about 12 feet, but in places they were 45 feet thick. Where recent work has been done the bank is about 25 feet thick. In the lowest 6 feet of the deposit there are many large undecomposed bowlders, but above this zone the material is gravel and sand not very strongly cemented. Most of the gold lies at and near the bottom. In general, it is rather fine. Some of the ground has run as high as $7,000 to the acre. The bedrock is greenstone, the slope of which is not more than 2 feet in 100 feet. The mine is equipped for hydraulicking, three giants being used. The water is brought 1½ miles, at a pressure of only about 85 feet, from the upper part of the stream on which the mine is located. A derrick is used for handling the bowlders. The property has an area of 240 acres, a large part of which remains to be worked.

In addition to the mines on Forest Creek already described, there are some other small producers. In the early days of placer mining in Oregon, Forest Creek was among the most productive areas.

PICKETT CREEK DISTRICT.

In the Pickett Creek district the two most important mines are the Big Four and the Flanagan & Emerson.

BIG FOUR MINE.

The Big Four mine, owned by M. J. Merrill, of Portland, Oreg., is 15 miles northwest of Grants Pass on Pickett Creek, one-third of a mile from the left bank of Rogue River. The property embraces

200 acres, chiefly on a bench of slate bedrock overlooking Pickett Creek and 300 feet above the level of Rogue River. The gravel ranges from 30 to 70 feet in thickness, and is in part clearly stratified. The 14 feet of red earthy sand and clay overburden is said to contain fine gold that can be saved, but the larger pieces are in the bottom gravel.

The lower 12 feet of gravel contains well-rounded cobblestones, the largest being 6 inches in diameter. At the bottom a few bowlders, generally slate, rest on the bedrock, and from 2 to 4 feet of the bottom gravel is partly cemented. The rim rock rises abruptly and slates are much crushed and faulted, forming a terrace on the northwest toward Pickett Creek. The old channel is 250 feet in width and 30 feet deep below the slate-rim terrace, from which the gravel capping has been in part mined away. The water is supplied from Pickett Creek at a head of 200 feet, two giants being run for a large portion of the year. The mine has been operated, during the season when water is obtainable, for many years.

FLANAGAN & EMERSON MINE.

The Flanagan & Emerson mine is on the left bank of Rogue River, 13 miles northwest of Grants Pass and about a mile above the mouth of Pickett Creek. Approximately 5 acres of gravel has already been mined from a slate bedrock terrace 30 feet above the river. The mine face exposes 50 feet of fine gravel containing a small amount of sand near the middle and at the top.

On the river side of the mine a portion of the gravel appears to have been washed away and replaced by a later deposit.

The slate bedrock is much twisted and faulted. The strike is N. 20° E. and the dip 45° SE.

In the neighborhood of the mine, especially toward the south, in an east bend of Rogue River, there is a broad tract evidently containing extensive deposits of river gravel. To judge from the tests reported by Clarence H. Mace,[1] this tract is worthy the attention of those looking for dredging ground.

GALICE DISTRICT.

The placers of the Galice district are noted especially on account of those connected with the old channel of the second cycle of erosion described on pages 98–101. There have been, however, extensive washings of the late gravels on Galice Creek.

The Galice Consolidated Mines Co. owns nearly all the property, about 30 claims, along Galice Creek, except five claims about the forks of the creek, which are controlled by the Galice Placer Mines Co.

[1] Min. and Sci. Press, p. 437, Mar. 23, 1912.

The gravels of this creek were rich. Possibly some of their gold was derived from the old channel as well as from the adjacent mountain slopes, which contain many gold prospects. Most of the stream gravels along Galice Creek have been mined out, except a portion of the Galice Placer Mines Co. property which is managed by Daniel Green, of Galice.

One of the most productive as well as novel and persistent placers of the Galice region, except, of course, the Old Channel mine, is that of Gold Bar and Rocky Gulch, on the left bank of Rogue River, 1½ miles below Galice. It is operated by H. L. Lewis and L. L. Jewell. Water for the mine is taken from Rocky Gulch to secure a 200-foot head for a 12-inch supply pipe.

The gravel forms a bar on the river and rises to a broad bench 18 feet above the river. About 10 per cent of the pebbles are from 3 to 6 inches in diameter and the rest are smaller.

A steam shovel with a 30-foot beam and scoop of large capacity recovers the gravel and raises it about 14 feet from a point below the river level to the hopper of the washer. A strong stream from a 12-inch pipe washes the gravel through a revolving screen, which takes out the coarse gravel, the fine being discharged into 300 feet of gently sloping sluice boxes. Only a small part of the available ground has yet been worked.

Two miles below Galice, 25 feet above water level, on the right bank of Rogue River, is a small placer, known as the Dean and Corliss, which opens the edge of a prominent terrace that may contain gravel remnants of a higher and richer channel. This property has recently been sold and additional water is being secured.

The success of dredging in the Foots Creek district has led to other attempts farther down Rogue River, but as yet none have been long continued. The latest attempt that has come to my attention was by the Scandinavian Dredge Co., on a bar along the right bank of Rogue River, 5 miles below Galice or 1½ miles below the Almeda mine.

Silver Creek flows into Illinois River, but from its upper portion, where Cheldelin and others have been mining, Galice is the easiest source of supplies, so it is generally considered a part of the Galice region.

On Silver Creek landslides have played an important part in contributing débris to block the stream, and at one point near the falls a large tunnel is already partly completed to make an outlet for an extensive body of gravel reported to be auriferous. Farther up Silver Creek there are a number of placers and among them are those operated by J. W. Baker and Peter Cheldelin, who have continued work for a number of years.

LOWER ROGUE RIVER DISTRICT.

GENERAL FEATURES.

About Grants Pass, Gold Hill, and Medford the valley of Rogue River has broad alluvial flats extensively used for farms and orchards, but a dozen miles northwest of Grants Pass, at Hellgate, Rogue River enters a rugged canyon, which continues, with only here and there a few small flood-plain benches, to the sea. The more rugged parts of the canyon are cut in igneous rocks and the wider portions lie in softer slates, which form benches for the deposition of gravels.

On Rogue River, for 4 miles below Hellgate, there are no prominent gravel benches, but from that point to the Almeda mine, a distance of 6 miles, in the Galice district, where the slates prevail, bars and benches are common. Below Almeda igneous rocks again prevail for over a dozen miles to Whisky Run, where slates and gravel deposits reappear in the Lower Rogue River district and continue for many miles with much irregularity and in general decreasing richness to the mouth of Illinois River.

TYEE BAR MINE.

The Tyee Bar placer on the left bank of Rogue River, about 1½ miles below Whisky Run, although not large, embraces a number of acres. Much of the bar was worked over years ago and reported rich. It was reopened in the summer of 1911, but was not yet producing at the time of my examination. The bedrock is composed of slates which adjoin the igneous rocks that contain so many prospective mines about Whisky and Rum creeks.

HORSESHOE BAR MINE.

Farther down the river there are small placers on benches 35 to 50 feet above the river at Pyles Bar, Black Bar, and Little Windy Bar, but at Horseshoe Bar, about 20 miles below Galice, the mining is more extensive and is within 10 feet of the river level. The Horseshoe Bar placer mine is owned by E. G. Francis, of Dothan, and W. A. Wise and T. P. Wise, of Portland, Oreg. The property consists of two claims of 20 acres each. Water is supplied by nearly a mile of ditch and a 9-inch pipe that is bridged over Rogue River to the bar at an elevation of about 10 feet above the river and delivered at a pressure of 150 feet. Another water supply from near-by gulches gives a head of 100 feet to wash the gravel into the pit, from which with a 3-inch nozzle under 150 feet pressure the gravel is raised 8 feet through an elevator to 150 feet of sluice boxes.

Some bench gravels about 80 feet above the bar have been partly washed away and have contributed to the production of the bar. With one giant and elevator, it is said, 150 cubic yards can be handled daily, and much of the bar is yet available.

A short distance below the Horseshoe Bar mine are other smaller mines, the Tennessee 1 and 2, owned in part by the same company.

BATTLE BAR MINE.

At Battle Bar, on the left bank of Rogue River a little above the mouth of Ditch Creek, a terrace 20 to 25 feet above the river is capped by gravel that has been tested by a small placer and said to yield good values. I saw it only across the river, but the deposit appears to be similar to that of Winkle Bar, a mile farther down the river.

WINKLE BAR MINE.

Nearly a mile below the mouth of Ditch Creek and 26 miles below Galice, on the right bank of Rogue River, is a large terrace known as Winkle Bar, that contains perhaps 30 acres. The slate bedrock terrace rises about 15 feet above low water in the river and is capped by 20 to 30 feet of gravel which is generally coarse, half of it consisting of bowlders over 5 inches in diameter. A small placer operated here some years ago and a test shaft encourages the Winkle Bar Developing Co. to plan for larger operations. Ditch Creek, with a few miles of ditch, will supply water with a head of 120 feet. The gold is fine and will require special precaution for its recovery.

RED RIVER GOLD MINING & MILLING CO. MINE.

The Red River Gold Mining & Milling Co. has eight claims on the low terraces on both banks of Rogue River just below the mouth of John Mule Creek and about 30 miles below Galice. The slate floor of the mine is 20 feet above the river. It is capped by 30 feet of gravel, which is covered by an overburden of fine material 35 feet in thickness. The overburden is slippery and is separated from the gravel by a sharp line. The gravel is mostly coarse, the largest bowlders being 15 inches in diameter.

The water supply comes from John Mule Creek through 3½ miles of 4-foot flume and ditch, giving at the mine approximately a 260-foot head for one 9-inch and two 6-inch nozzles.

The gravel is forced up over a grizzly 12 feet wide to a height of 15 feet. Only about 5 per cent of the material covering the gold goes through the screen of the grizzly to the sluice boxes. The gold is fine and in general hard to save. On the left bank it is said to be coarser.

Much of this property was mined over years ago, and several acres have been mined recently, leaving but a small portion of the original available material.

Statements vary greatly as to the amount of production. The removal of the overburden has been a serious handicap. The present owners secured the property within the last few years and are making preparations for more extensive work.

Farther down the river, especially at Paradise Bar and Big Bend, a number of other companies have operated more or less extensively, but none of them appear to have been successful.

APPLEGATE DISTRICT.

The chief mines of the Applegate district are located on small streams flowing into Applegate River. The most important are the Layton mine, on Ferris Gulch; the Johnston and the Benson mines, on Humbug Creek; and the Brantner mine, near the mouth of Keeler Creek.

LAYTON MINE.

The Layton mine is part of the estate of J. F. Layton. The average thickness of the gravels is about 25 feet and the width from rim to rim of the pay channel is more than 200 feet. In much of the material the pebbles are less than 6 inches in diameter and are generally subangular. The largest bowlders are in the bottom of the deposit and in places are considerably decomposed. Most of the gold is found in an old channel about 15 feet below the level of the present stream bed. In this channel the fall is about 4 feet in 100 feet. The gold in general is in small flakes, but nuggets are also found. The bedrock is greenstone, which in places is distinctly vesicular and greatly fractured and veined, some of the veinlets being as much as 4 inches in width. Narrow bands of slaty rock are interbedded with the volcanic rocks, which strike about N. 40° E. and dip to the southeast.

Mining is carried on each year from February until September. The early miners had a small ditch with a head of 100 feet, but Mr. Layton put in two ditches, the upper of which is 21 miles long and the lower 18 miles. The water of both ditches comes from Williams Creek. Two giants are used under a head of about 300 feet. Five men are generally employed, and the amount mined off each year is somewhat more than 1 acre. The property was secured by the present owners in 1877 and since that date mining has been carried on each year. A considerable area of good ground remains to be washed.

JOHNSTON MINE.

The Johnston mine is in sec. 11, T. 38 S., R. 4 W., at the junction of the west branch with the main Humbug Creek. The present owner is W. H. Johnston. The bank averages about 8 feet in thickness and contains considerable clay, in which most of the gold is found. Bowlders of greenstone and granodiorite from 6 inches to more than 8 feet in diameter are present. Much of the mining has been confined to the bed of the stream. The bedrock consists of fine-grained greenstone, much fractured and veined. The mine is equipped for hydraulicking, the waters being brought from Humbug Creek. The supply of water is so scanty that, in general, the mine

can not be operated for more than three months each year. Mining has been done on this stream for more than 30 years, during which time more than 30 acres has been worked.

BENSON MINE.

The Benson mine, owned by S. L. Benson, is on Humbug Creek in sec. 14, T. 38 S., R. 4 W. The property comprises about 1 mile of the stream bed. The gravels are about 20 feet in thickness and contain many large angular and subangular bowlders, which are rather uniformly distributed throughout the section of the deposit. The gold is found mainly in the bottom. The bedrock is greenstone. This mine has been in operation for many years, but was not equipped for hydraulicking until the spring of 1908.

BRANTNER MINE.

The Brantner mine, owned by D. H. Mansfield, is on Applegate River near the mouth of Keeler Creek. In the present workings the sands and gravels have a thickness of 30 to 35 feet and show distinct stratification. Many large angular and subangular bowlders, chiefly of greenstone and comparatively unaltered, are found at and near the base of the deposit. All the material above this is fairly well rounded and contains few bowlders. The surface of the terrace now being worked is about 40 feet above Applegate River. The bedrock is decomposed greenstone. The mine is equipped for hydraulicking the water used having a pressure of about 100 feet, and there is sufficient water to operate the mine for about three months in the year. The large bowlders are handled by derrick. Altogether more than 20 acres have been mined, and considerable good ground remains to be washed.

WILLIAMS CREEK DISTRICT.

The chief placer mines in the Williams Creek district are the Horsehead mine, on a branch of Williams Creek; the Miller & Savage mine, on Miller Creek; and the Oscar placer, on Oscar Creek.

HORSEHEAD MINE.

The Horsehead mine, owned by Alexander Watt, is in the SE. ¼ sec. 21, T. 38 S., R. 5 W. The gravels range in thickness from a few feet to 30 feet, with an average of about 18 feet. The deposit contains many angular and subangular bowlders considerably more than 1 foot in diameter which are somewhat uniformly distributed throughout the section. Many of the bowlders are greenstone, but some are granodiorite. The finer materials are of a grayish to reddish color. The gold is distributed through the gravels and as a rule it is fine. The bedrock is granodiorite which has been fractured and crushed and in places has been disintegrated and decomposed to

a depth of more than 10 feet. An area of more than 10 acres has been mined. The property is equipped for hydraulicking. The water is brought from Munger Creek, the ditch being 8 miles long.

MILLER & SAVAGE MINE.

The Miller & Savage mine is on Miller Creek in sec. 25, T. 37 S., R. 5 W. The gravels range in thickness from 6 to 30 feet, the average being about 18 feet. Many bowlders exceeding 1 foot in diameter are present, the largest being at the bottom of the deposit. The gold is mostly fine, but nuggets of large size have been found. The largest nugget, which was found several years ago, is said to have weighed more than 13 ounces. The mine is equipped for hydraulicking. The present owners have mined each year since 1904, and considerable good ground remains to be washed.

OSCAR CREEK MINE.

The Oscar Creek mine, comprising more than 300 acres, is on Oscar Creek, a small stream which flows into Applegate River. The gravels have an average thickness of about 12 feet and contain many rounded bowlders of medium size. The materials are not strongly cemented. The gold is found in flakes and in nuggets. The equipment consists of two giants, 1,100 feet of pipe, 300 feet of flume, and 3 miles of ditches. The supply of water is sufficient to carry on operations for about four months of the year. It is said that the property has produced more than $35,000.

ALTHOUSE AND SUCKER CREEKS DISTRICT.

From the gravels of Althouse and Sucker creeks a large amount of gold was washed in the early days of placer mining in Oregon, but for several years the production has not been great, as the best ground was worked many years ago. During 1907 the production of the streams of this district probably did not exceed $6,000. There are no large mines, but numerous small ones, among which are the Jumbo, the Mountain Slide, the Slide, and the Yeager, on Sucker Creek and its branches. On Althouse Creek some work is being done on the Layman property, and recently the Klamath Development Co. acquired eight claims near Grass Flat. Some new ground was also being opened in 1911 at the mouth of Portuguese Gulch, a small branch of Althouse Creek near its head.

WALDO DISTRICT.

DEVELOPMENT.

In the Waldo district there are three important placer mines, the High Gravel or Allen Gulch mine, the Deep Gravel mine, and the Logan, Simmons & Cameron mine. Of these the Logan mine has been, at least in recent years, the most important producer.

After prospecting portions of the extensive gravel placers north of Waldo the three mines mentioned were purchased several years ago by the Waldo Consolidated Gold Mining Co. of Oregon. The property controlled is said to embrace 4,000 acres of hydraulicking ground, and the Logan mine for some time was operated by this company.

The High Gravel mine is in gravel of Cretaceous age and is described on pages 94–95. The Deep Gravel and Logan mines, although partly on gravel of Cretaceous age, are mainly in gravel of the third cycle of erosion and will be described here.

DEEP GRAVEL MINE.

The Deep Gravel mine is about 1 mile northwest of Waldo. The property comprises about 560 acres in secs. 20, 21, and 28, T. 40 S., R. 8 W., and was until recently owned by the Deep Gravel Mining Co. The main workings are in Butcher Gulch and its tributary gulches. The gravels of these gulches are included in a bench which extends from the head of Butcher Gulch to the west fork of Illinois River. The upper limit of the bench is about 1½ miles from the west fork and about 125 feet higher than the bed of this stream. The most recent workings are in Joe Smith Gulch, an eastern tributary of Butcher Gulch, where an area of more than 10 acres has been mined. At the upper end of these workings the gravels are about 12 feet in thickness. At the lower end they are more than 60 feet thick, and the bank consists of gravel and sand containing practically no bowlders, except in the lowest 10 feet. Even there few bowlders exceed 1 foot in diameter. Stratification is well shown. The bedrocks in Joe Smith Gulch consist of purplish conglomerates of Cretaceous age, similar to the conglomerates that are being mined at the High Gravel mine. As these conglomerates of the Deep Gravel mine have not yet been well prospected, their gold content is not known.

The mine pit of Joe Smith Gulch is 1,500 feet from the west fork of Illinois River. The elevation of the bedrock in the mine pit is more than 30 feet below the stream bed of the west fork, a fact that has greatly increased the difficulties of mining, necessitating the use of a hydraulic elevator, which is situated at the lower end of a sluice with riffles. The pay gravel from the bank is first washed through the sluice, the coarse gold being caught on the riffles. Then the material, including the fine gold, is carried up 46 feet by the elevator, the water pressure used being about 200 feet. At the head of the elevator is a 4-foot flume, 400 feet in length, in which are wooden riffles placed about 1½ inches apart, and parallel to the length of the flume. A beveled steel strip is attached to the upper surface of each riffle. These steel strips are slightly wider than the riffles, and when they are set in place, are about three-fourths of an inch apart.

A clean-up is made about once a month. The gold is saved by amalgamation, and is very fine. The concentrates are sold for their value in platinum, osmium, and iridium.

The water used in the pit and in the elevator is brought by two ditches from the east fork of Illinois River. The longer ditch is about 4 miles in length. A race about 7,000 feet long was used for many years when the gravels being mined were at an elevation greater than that of the outlet of the race. At present only the lower end is used.

The history of the Deep Gravel mine dates back for more than 30 years. The first owners were George and Walter Simmons. In 1878 Wimer & Sons bought a half interest, and in 1888 they secured all rights to the property. In 1900 the Deep Gravel Mining Co. became the owner, and sold it to the Waldo Consolidated Gold Mining Co. of Oregon.

LOGAN, SIMMONS & CAMERON MINE.

The Logan, Simmons & Cameron mine, one of the largest placers in the State, is northeast of Waldo, the present workings being in sec. 22, T. 40 S., R. 8 W. The recent workings are on French Flat, where about 3 acres have been mined. Here the bank consists of gravel, sand, and clay, the thickness ranging from a few feet to 15 feet. Much of the material is fine; only a few bowlders are present, nearly all of which are less than 6 inches in diameter. The bedrock is purplish Cretaceous conglomerate, which has been fractured, fissured, and to some extent veined. The slope of the bedrock is very gentle.

An elevator raises the material 38 feet. The water from one of the three ditches has a pressure of 325 feet and is used in the elevator; that from another is used in two giants in the pit; and that from the third is used in forcing the tailings from the end of the sluice at the head of the elevator. Mining is carried on for about eight months of the year.

The old workings on this property are in Carroll Slough, more than a mile north of the present pit on French Flat. The gravels have been mined in a north-south direction for more than a mile. The average width of the cut is about one-eighth mile, the average depth about 18 feet. The bedrock is made up in some places of serpentine and in others of Cretaceous conglomerates and sandstones.

This mine has been operated for about 25 years, but not until a few years ago was work begun on French Flat, where there is a considerable area of auriferous gravels.

JOSEPHINE CREEK DISTRICT.

Josephine Creek drains an area of contacts between greenstone cut by serpentine and serpentine penetrated by many small dikes, chiefly

of dacite porphyry. Vein deposits, locally with rich pockets, have attracted much attention through the richness of the placers.

Josephine Creek lies wholly in serpentine, and its gravel bed contains very little gold above the mouth of Canyon Creek as compared with the amount found below that point, where the gold is contributed mainly by Canyon Creek, Fiddlers Gulch, and Days Gulch, which come in from the contact region on the northwest.

The placers of Josephine Creek, considering the length of the stream, are numerous and though generally hydraulic are not large. They have long been active and will so continue for many years to come, owing chiefly to the limitations in the water supply and to the more or less firmly cemented condition of the gravel, which renders mining difficult and progress slow.

The greater portion of the present bed of Josephine Creek and its branches was mined out many years ago and on account of the cemented condition of the benches there was much drifting by the early miners. The principal creek-bed placer is on Canyon Creek, 1 mile below the forks at Rich Gulch (102 on Pl. VI, p. 46), where the valley widens somewhat on the entrance of a small stream from the west. Many acres have been mined over, in some places three times on the stream bed and low benches, and considerable josephinite is said to have been found with the gold at this locality.

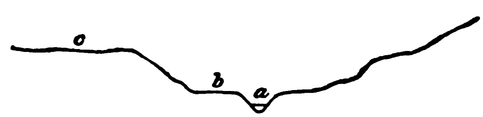


FIGURE 21.—Cross-section profile of Josephine Creek. *a*, Valley below mouth of Fiddlers Gulch, showing terraces 30 feet (*b*) and 150 feet (*c*) above the stream.

Farther down Canyon Creek and on Josephine Creek the mining is now for the most part limited to the higher and harder coarse gravel benches, of which there are large terraces near the junction of Canyon and Josephine creeks where the Bowden (106), China Bow (105), and other mines have been operating. (See Pl. VI, p. 46.) From this point prominent terraces border Josephine Creek to its mouth. The cross section (fig. 21) shows the relation of the terraces to the present stream.

The 30-foot terrace (2, fig. 21) is in places 100 feet wide. Its gravel, 4 to 30 feet thick, is composed chiefly of serpentine and greenstone pebbles and a few bowlders. It is not cemented and, being rich and easily worked, like the present stream bed, it has been completely mined out. The 150-foot terrace is capped by 5 to 25 feet of gravel, which near the surface is generally decomposed and is red or yellowish, but below that point the gravel contains more light-colored pebbles of granitic rock and is more or less firmly cemented. Bowlders are common, and the cemented gravel is used as a false bedrock in mining off the rotten portion, which is about 12 feet in thickness.

The mining of the decomposed surface portion of the cemented gravel on the 150-foot terrace at four places (see Pl. VI, p. 46; Bowden, 106; Gold King, 108; Gold Leaf, 109; Illinois and Josephine, 110) within 2 miles of the mouth of Canyon Creek is evidence that these cemented coarse gravels, composed chiefly of serpentine and greenstone cobblestones, contain gold. Concerning this matter, Mr. B. F. Hogue, of Kerby, Oreg., who has been a practical miner, informs me that he has blasted the cemented gravel, removed the bowlders, and crushed and washed the remainder, the average return being $1.40 a day. Two cubic yards that he had measured and tested averaged 70 cents each. Though much of the cement contains little gold, perhaps as little as 5 cents per cubic yard, other portions of it are much richer. On the left bank of Canyon Creek, where Mr. Hogue mined a mass that measured 6 by 8 by 16 feet, he got $45, which is an average of nearly $1.60 a cubic yard. This amount is exceptionally high and tends to raise the general average. Though it is certain that gold can be won economically from the weather-softened cemented gravel, the weather softening is an exceedingly slow and irregular process. On the other hand, the gold does not appear to be sufficiently plentiful to warrant the more expensive method of milling.

ILLINOIS RIVER DISTRICT.

In the Illinois River valley there are two groups of placers, one in the vicinity of Waldo (see pp. 118–120) and the other scattered along the river below the mouth of Josephine Creek. The most important mines of the latter group are the Anderson & Wilson mine and the mine at the mouth of Sixmile Creek.

ANDERSON & WILSON MINE.

On the right bank of Illinois River, just below the mouth of Josephine Creek, there is a prominent gravel bench which extends down the river with slight interruptions for nearly 2 miles. On this bench, one-third of a mile below the mouth of Josephine Creek, is the small opening of the Ray mine (88, Pl. VI, p. 46), now idle, on a gravel plain 200 yards in width with gravel 10 to 18 feet in thickness.

A short distance beyond the Ray mine a shoulder of serpentine juts toward the river and forms an embankment beyond which accumulated the large body of gravel so extensively worked in the Anderson & Wilson mine, which extends along the river for nearly half a mile.

Mining has been carried on in this placer for many years under the management of G. E. Anderson. Work was begun on the bar and low benches on the north and gradually extended south to the higher benches adjoining the serpentine shoulder.

From the lower benches and bar the mining extended across the river and included portions of Cow Flat, which was not only rich in gold but also in platinum. On the lower benches the gravels are about 20 feet thick and in places have been mined for a distance of one-eighth of a mile back from the stream, where the slope rises steeply and the limit of the bench is reached. The sand and gravels are of a buff color and well stratified. The largest bowlders lie in the lower 6 feet of the deposit.

More recent work has been done on a bench of serpentine south of the one described and about 75 feet above the river. The gravel of this bench is in some places 35 feet thick. The lower 6 feet of well-rounded gravel contains some bowlders. It is overlain by 10 feet of finer gravel and above this comes 20 feet of coarser, rather angular red gravel with fragments, the largest of which is 3 to 5 inches in diameter. The bottom gravel is composed chiefly of siliceous rocks, but the upper 10 feet is largely serpentine overwash from the hillside. A grizzly is used in mining this terrace to pile up the gravel, and a small portion of the cemented gravel at the bottom is left on the bedrock.

The gravel of the highest terrace worked in the season of 1910–11, at the south end of the mine is irregular, much oxidized, and decomposed.

The mine, including all the terraces, covers approximately 50 acres, and by far the greater part of the available gravel has been removed. The water for the mine comes from Fiddlers Gulch. A bridge carries it across the river in a 14-inch pipe and delivers it on the lower terraces with a head of 200 feet. Recently G. E. Anderson has installed a Ruble elevator and rearranged his entire hydraulic plant.

A mile farther down the river on the left bank is a large terrace, 75 to 100 feet above the river, opposite the mouth of Deer Creek. The terrace is capped by gravel that has been partly mined by G. E. Anderson in the Coonskin claim.

SIXMILE CREEK MINE.

Below the mouth of Deer Creek there are several small placers near the river level, but a larger one was operated some years ago on a bench at the mouth of Sixmile Creek, between 500 and 600 feet above the river. The bench is longest parallel to the river. About an acre of the gravel capping has been washed away, leaving the greater portion in place. The gravel is 20 feet thick, moderately coarse, and in part decomposed. The bedrock is serpentine, but has not furnished many pebbles.

A prominent terrace, corresponding approximately to that of the Sixmile Creek mine, occurs at several points along the river trail above the mouth of Sixmile Creek. The gravel capping exposed in

some of the gulches is thick and a considerable portion is cemented firmly, reminding one of the old-channel gravel on Briggs Creek. This high terrace of cemented gravel occurs at a point where the old channel might be expected to leave the present course of Illinois River (see p. 98), and it is possible that it is a remnant of the old channel of the Illinois to Rogue River at Galice. There appears to be a large mass of gravel on top of this terrace, and I saw no place where it had been fairly tested.

BRIGGS CREEK DISTRICT.

Briggs Creek lies in the course of the old channel between Galice Creek and Illinois River. Though the canyon is narrow and rugged and the gravel bodies are less continuous, a number of small sluices and hydraulic placers are worked during the rainy season. The bedrock is generally greenstone, in contrast with that of Galice Creek.

The John West mine, near the Old Dasher place and the mouth of Soldier Creek, is on a bench 25 feet above the creek. The bench is 100 feet wide and capped by 8 feet of gravel. Water is obtained at a 150-foot head through a 3-inch nozzle. Emerson & Fick are located on Red Dog Creek, and Coons & McDow work placers on the lower bench of Onion Creek. The last two mines are near gulches that head against the old channel capping about Column Rock, from which they are supposed to derive coarse gold.

Farther up Briggs Creek is the Courier mine, and above it lies a mine of seven claims owned by Robert F. Miller. The Miller mine is opened up in a pit of about 1½ acres. Red earth, sand, and gravel, 20 feet thick, overlie 5 feet of coarse gravel. The gold, though found chiefly in the coarse gravel, is scattered through the mass and is supposed to come from the north, where a great body of serpentine borders the greenstone. On a side stream in the neighborhood of the contact is the W. H. Barr mine, which was not seen.

PLACERS ON RESIDUAL DEPOSITS.

In the spring of 1911 there was considerable excitement over the reported discoveries of rich ground on the Higgins and other claims, about 20 miles by trail northwest of Kerby. The gold was won chiefly by washing the residual deposits on mineralized contacts between serpentine and greenstone. As the placer mining is considered by the miners to be merely incidental to the discovery and development of lode mines, these mines were noted in this paper under the lode mines, but the placer phase is of so much importance that special attention is called to it. In fact it is, at least to the local miner, one of the most important phases of mining in southwest Oregon. The residual earthy deposits along the contacts of serpentine and greenstone should be thoroughly prospected.

The Higgins mine is the most widely known example of this phase, but the same method has been successfully applied by T. M. Anderson and is being installed at the Casey mine on Rancherie Creek and the Miller mine on Baby Foot Creek, as well as elsewhere in the same region. In the divide regions water is most difficult to find, but generally a large amount of it is not needed.

BEACH PLACERS.

DEVELOPMENT OF MINING.

The fine gold of the Oregon beach sand has attracted much attention for years and many attempts, more or less successful, have been made to mine it. In Oregon gold was first discovered along the beach at Port Orford and the mouth of Whisky Run, where work was commenced in 1852. Four years later the miners prospected the rivers, and work on the elevated beaches at the eastern edge of the coastal plain at the Blanco and the Sixes mines followed in 1871. The beach mines were rich in places and were extensively worked.

In nature's assorting process on the beach the heavy minerals get together and many of them are black, so that black sand has come generally to be regarded as auriferous. The successful mining of black sands depends on the saving not only of the gold but all the other valuable minerals it contains. Among the accessory minerals platinum is the most important and will be considered later by itself.

The most important beach-mining localities of Oregon are in the vicinity of Bandon and Cape Blanco.

BANDON DISTRICT.

Many years ago the beach mines were of much importance in the Bandon region, especially those near the mouth of Whisky Run. Occasionally a man would take out as much as $100 a day, but generally the gold was so fine that it was saved with great difficulty. At the present time the outlook is much more encouraging. Mr. J. A. Gardner, of Bandon, Oreg., wrote me on May 29, 1912, that he was using with a good degree of success two of Eccleston's tension concentrators at the mouth of Gold Run, and it appeared that at last a successful method had been found to work these deposits not only on the present beach but also on the elevated beaches.

The most extensive elevated beach mining in the Bandon region was carried on some years ago 6 miles northeast of Bandon at the foot of a bluff extending from Threemile Creek to the head of the Lagoons. The plain at the base of the sea cliff is about 200 feet above sea level, and the black sand lies about 30 feet below the level of the plain; that is, at an elevation of about 170 feet above the present sea level.

In the Rose mine, worked at that time, the bedrock shale was laid bare and the black sand well exposed. It generally lies next to the bedrock and stretches along the foot of the bluff for several miles. The belt of black sand is about 150 feet wide. In cross section it is lenticular in shape, about 4 feet thick in the middle, tapering to an edge on each side, with the coarsest material, including gold, near the landward border, where it is highest and represents the most vigorous wave action. On account of the thick coating (30 feet) of sand and gravel which overlies the black sand an attempt was made to remove the auriferous sand by means of tunnels. Logs and bowlders of various sizes are found occasionally in the black sand.

The mineral composition of black sand varies with each locality, but at the one under consideration it is composed chiefly of garnet, magnetite, ilmenite, and chromite with a smaller amount of zircon, epidote, and a few other minerals. Gold is generally found more or less abundantly, and platinum with iridosmine is locally found in small quantities among the heavy concentrates. These metals should always be looked after, for if abundant they pay well for mining.

CAPE BLANCO DISTRICT.

The Cape Blanco district includes the small beach placers at Port Orford and Ophir to the south as well as the elevated-beach mines, the Blanco and the Sixes mines, which lie a few miles to the east and northeast, respectively.

The Blanco mine is about midway between Port Orford and Langlois, along the inner border of the coastal plain, at the foot of Madden Butte, in the NE. ¼ sec. 4, T. 32 S., R. 15 W. When last seen it was operated by Mr. Cyrus Madden with about 500 feet of sluices and 7 burlap tables for catching the fine gold, which constitutes about half the total product. Platinum metals occur with the gold at this point and are about one-twentieth as abundant. The section exposed in the mine includes about 8 feet of wind-blown material next to the surface, below which lies 12 to 20 feet of sand with small black layers and some gravel. Some of the dark layers are coated by oxide of iron, and one of these is used as a bedrock on which to wash the overlying material. The real bedrock, which lies 10 feet below, is Cretaceous shale, but it is too low for drainage across the plain. The working season usually lasts six months, from November to May, and the mine from 1898 to 1900 yielded over $1,100 annually. The beds of sand and gravel of the ancient beach dip gently (10°) westward and overlap the older rocks at the base of Madden Butte. The mine already covers an area of several acres, and there is reason to expect that it will continue profitable farther along the shore, especially at deeper levels, if possible to drain to bedrock.

The Sixes mine is located about 2½ miles south of Denmark, near the line between secs. 27 and 34, T. 31 S., R. 15 W., and is operated by Mr. W. P. Butler, of Lakeport, Cal. Like the Blanco mine, it lies along the eastern border of the coastal plain, at an altitude of nearly 200 feet above sea level. The mine covers about an acre and has a depth below the surface of about 12 feet, exposing along the eastern border the following section:

Section of the Sixes mine, 2½ miles south of Denmark.

	Feet.
Surface material, wind-blown sand and soil	5
Gray sand with bowlders	2
Black sand with bowlders	2½

The whole 9½ feet of material is more or less distinctly stratified and dips gently westward, away from the shore, which is formed of crushed sandstone and shale of Cretaceous age. This bedrock series is well exposed in the eastern portion of the mine and contains rock oyster borings. The decomposed fine sediments yield tough bluish clay, which on the surface for 6 inches or so is stained reddish and becomes more granular, affording a good bedrock for mining. The gravel is washed into a pool and raised 15 feet by a hydraulic elevator to get drainage for sluicing and tables. Much of the gold is fine and is associated with platinum metals in sufficient quantities to make the saving of them a matter of some importance.

The lack of adequate water supply and good drainage renders mining so expensive as to retard the development of hydraulic mining along this promising old beach. It would seem to be an encouraging locality to test by a modern dredge.

ECKIS MINE.

On the Meeks mine, near Port Orford, Mr. R. G. Eckis has been running an Eccleston tension concentrator 24 hours a day for some time. He is using a giant to wash the sand into a sluice box in the bottom of which he has a screen, thus taking the heavy black sand out in an undercurrent. This product is then run over the concentrator. He reports that he is securing 80 per cent of the gold, platinum, and iridosmine, and he says his concentrates run over $8,000 a ton total value. One machine handles the undercurrent from 150 cubic yards a day.

According to the latest report from that region the most productive mine in Curry County is the Kalamazoo ocean-beach sand mine in the Ophir district, near Corbin.

PLATINUM.

The Klamath Mountains have long been known as the principal source of platinum in the United States. Although the output is small, the high value of the metal makes the occurrence important. The platinum is recovered wholly as a by-product in placer mining for gold. In the early days, when its value was not appreciated, the platinum was lost, but now that its value is better known it is generally looked for with care by placer miners.

The annual production of platinum in southwest Oregon varies considerably. In 1906 it was apparently largest, but the exact amount is not known. Since then it has been as shown in the following table, coming chiefly from the beach sand mines of Coos and Curry counties:

Production of platinum in Oregon from 1907 to 1910, inclusive.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Ounces.			*Ounces.*	
1907	57	$1,690	1909	277	$4,940
1908	44	836	1910	53	1,121

According to Waldemar Lindgren, the principal production of platinum reported in Oregon in 1909 and 1910 came from beach mines near Port Orford, in Curry County, and from the vicinity of Bullards in Coos County.

Outside of the two points mentioned in Coos and Curry counties, platinum has been recovered in placer mines at numerous other points, most important among which, perhaps, are the Blanco and the Madden mines on an elevated beach in Curry County. The following mines at one time promised well but are now closed: The Steam Beer mine on Cow Creek near Leland, the Old Channel diggings on Rogue River near Galice, the Big Four and Flanagan mines on Rogue River, near the mouth of Pickett Creek, besides many places on Illinois River near Waldo, and especially along Josephine Creek and on Illinois River just below the mouth of Josephine Creek.

Many machines have been devised for saving the fine gold and platinum of the beach sands, but of late the most successful has been the Eccleston tension concentrator. Three of these concentrators are now in successful use on the Oregon coast. Mr. J. A. Gardner, who is using two of these machines near Bandon, writes that he has been very successful in saving the fine gold and the platinum.

There is a large and promising field for successful black sand concentration along the present beach and the elevated beaches of the Oregon coast.

Although the production of platinum in Oregon in 1912 declined to 39 ounces, nevertheless the high prices stimulated the installation of modern machinery on the Oregon coast, and the production in 1913 probably increased considerably.

Peridotite and serpentine derived from it are generally considered to be the native rocks of platinum, and the abundance of serpentine in southwest Oregon may account for its presence in that region, although the platinum has not yet been found in place.

QUICKSILVER.

Quicksilver is widely distributed in southwest Oregon, and traces of its ore, cinnabar, can be found in concentrates of nearly all the placer mines. At a few points there has been extensive prospecting, which actually reached a small production, but the output is not separable from that of eastern Oregon. The total annual production of the State never exceeded a few hundred flasks. The deposits are very irregular and though fairly extensive are low grade.

The first localities developed are in the Roseburg quadrangle, northeast of Oakland, where cinnabar occurs scattered in Eocene sandstone about half a mile from a mass of intruded diabase. Much of the sandstone has been bleached as if by hot springs. The mines were soon abandoned and developments carried on farther north, first on Shoestring Creek and later on the Coast Fork of the Willamette in Lane County, where a small production was attained within the last few years, though the mine has since been closed.

At the last two localities the cinnabar occurs in connection with volcanic tuff, and the same is probably true of the occurrence near the edge of the lava field reported from the vicinity of Drew in the eastern portion of Douglas County.

Although several of the localities look promising, the ore is so low in grade that there is little hope of establishing a successful quicksilver industry in southwest Oregon.

NICKEL.

One of the most interesting ore deposits in southwest Oregon is that of nickel, which occurs in two forms, as the green silicate of nickel, genthite, near Riddles and as josephinite on Josephine Creek.

Nickel Mountain, a few miles west of Riddles,[1] is composed of peridotite, which is partly changed to serpentine. The olivine of the peridotite appears to be nickeliferous, and an alteration, possibly due in part to hydrothermal action, has resulted in the formation of a body of nickel ore sufficiently large to suggest the possibility of successful mining.

The deposit was owned originally by W. Q. Brown, of Riddles, Oreg., and under his management the Oregon Nickel Mines Co. prospected it quite extensively, but as yet no successful attempt has been made to work it.

The silicate of nickel, genthite, has been found in southwest Oregon only at Nickel Mountain. If the ore is wholly derived from the perid-

[1] Kay, G. F., U. S. Geol. Survey Bull. 315, p. 120, 1907.

otite by weathering it is rather surprising that this silicate of nickel is not more widely distributed in southwest Oregon, for the olivine at some other places in the peridotite contains nickel.

Josephinite is a mineralogic curiosity rather than an ore of economic value. It is composed of nickel and iron and is known only in the form of small nuggets from the placer mines of Josephine Creek within an area of peridotite and serpentine, from which the josephinite is supposed to have been derived.

COAL.

PRODUCTION AND CHARACTER.

In the production of coal Oregon ranks next to California among the Pacific States. Its greatest annual production was 109,641 tons in 1905, and in 1910 the output was 67,533 tons. Owing to the increased production of petroleum in California and its use for fuel there is less demand for coal and its output has decreased, as shown by the annual values of the coal output for 1900 to 1912 in the table on page 23.

The only productive coal field in Oregon, the Coos Bay coal field, is situated in the southwest portion of the State. Other small coal fields have been prospected, among which are the Upper Nehalem field in Columbia County, the Lower Nehalem in Clatsop and Tillamook counties, and the Yaquina field in Lincoln County.

In the southwest portion of the State outside of the Coos Bay field there are a number of coal prospects of more or less importance. (See fig. 22.) Some of these have been designated as coal fields, as the Eckley, in Curry County, the Eden, in Coos County, and the Rogue River valley field, in Jackson County, but prospects that are scarcely less important occur on Shasta Costa Creek in Curry County, in Camas Valley, on Lookingglass Creek, and on North Fork of Rogue River near Glide in Douglas County.

All the coal of southwest Oregon is associated with formations of Tertiary (Eocene) age, chiefly marine, but in part of brackish or fresh water origin on the swampy Eocene coast. The coal is lignitic in character, except the best coals of the Coos Bay field, which are properly regarded as subbituminous.

COOS BAY COAL FIELD.

GENERAL FEATURES.

The Coos Bay coal field lies about Coos Bay on the coast of Oregon, about one-third of the way from the California line to the mouth of Columbia River. It is in general elliptical in outline, 30 miles in length, and 12 miles in greatest breadth, the area being approximately 250 square miles, included in Tps. 24 to 29 S., Rs. 12, 13, and 14 W. (See fig. 23.)

The south end of the coal field is traversed by Coquille River and the north end by Coos River and Coos Bay, with its branching tidal sloughs, which drain about three-fourths of the field. In general the surface is an irregular table-land whose broad summit ranges in altitude from 500 to 800 feet above the sea. The slopes to the master streams and their alluvial plains are generally steep, but the slopes to the sloughs are for the most part gentle.

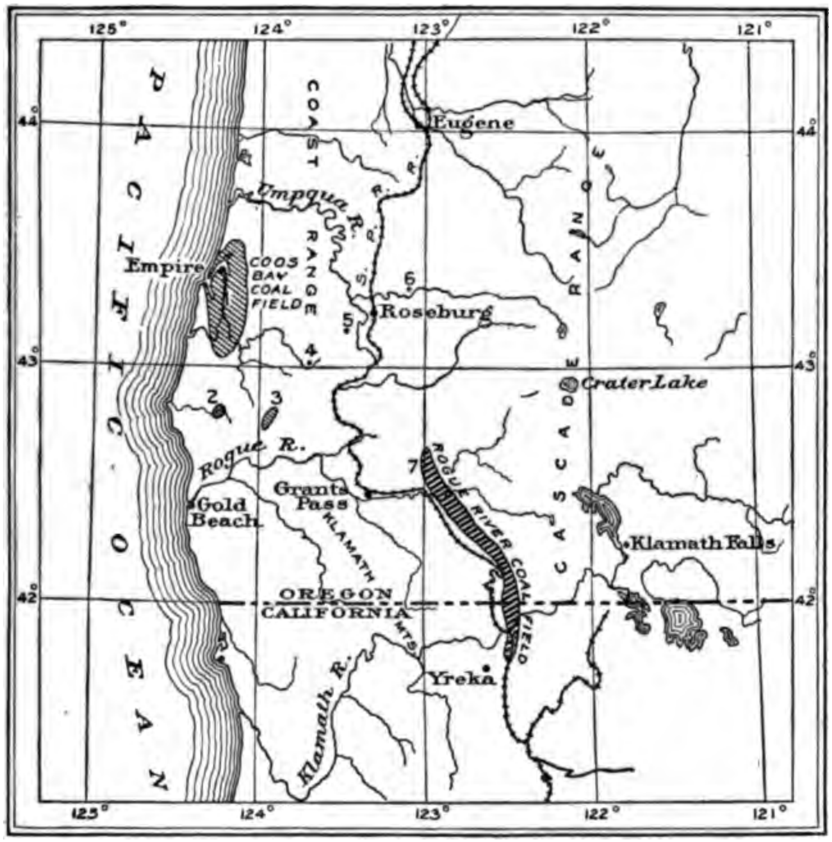


FIGURE 22.—Coal fields of southwest Oregon. 1, Coos Bay; 2, Eckley; 3, Eden Ridge; 4, Camas Valley; 5, Lookingglass; 6, North Fork of the Umpqua; 7, Rogue River valley.

The rivers and the bay are navigable and, with the railroad up Coquille River, afford convenient facilities for transporting the coal to market.

A survey of the Coos Bay region was made 12 years ago, and the results were published in the Nineteenth Annual Report of the Director of the Geological Survey [1] and in the Coos Bay folio.[2] The

[1] Diller, J. S., The Coos Bay coal field, Oreg.: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 3, pp. 309-376, 1899.

[2] Diller, J. S., U. S. Geol. Survey Geol. Atlas, Coos Bay folio (No. 73), 1901.

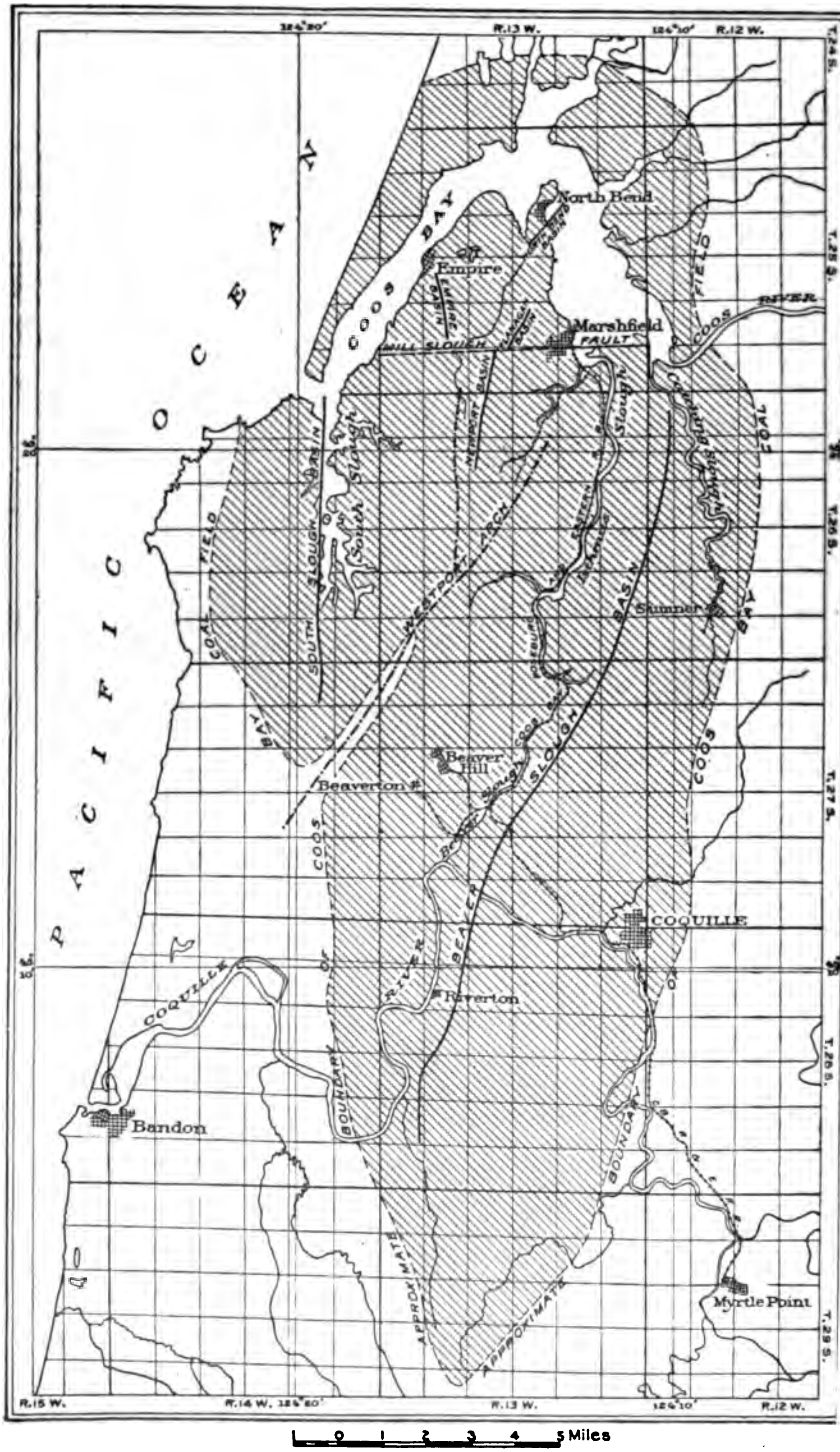


FIGURE 23.—Map of Coos Bay coal field.

maps then published show the outline and structure of the coal field, but in preparing them no attention was paid to land lines. Since then the field has been resurveyed, except the southern portion, and the results published in Bulletin 431.[1]

GEOLOGY.

STRATIGRAPHY.

The coal-bearing rocks of the Coos Bay region belong to the Arago group of the Eocene series. The rocks contain both fossil leaves and shells and present an especially interesting feature in the occurrence of fresh or brackish water shells within the coal beds, whereas between the coal beds and in places rather close to them purely marine fossils are occasionally found. The interstratification of these fossil-bearing beds evidently indicates alternate rising and sinking of the land close to sea level.

The Arago group has not been completely measured, but its total thickness is probably not less than 10,000 feet. The coal occurs in four zones distributed through about 8,000 feet of strata. By far the most important zone is that of the Newport coal, in the upper half of the mass.

STRUCTURE.

The general structure of the coal field is that of a basin containing a number of subordinate folds, whose axes are shown in figure 23 and a cross section in Plate IX. The principal fold, the Westport arch, divides the field into two subordinate basins, the Beaver Slough basin and the South Slough basin. The detailed structure of the field is complicated by faults and by a number of folds that give rise to smaller basins, among which may be mentioned the Newport, Flanagan, North Bend, and Empire basins.

The axis of the Westport arch trends N. 35° E. and, branching, pitches slightly in the same direction, so that on the southwestern border of the coal field, at the head of Sevenmile Creek, the arch completely separates the Beaver Slough and South Slough basins, but in the northern part of the field the two basins practically unite around the faulted end of the arch.

The Beaver Slough basin is by far the most extensive and important structural feature of this field. It is long and narrow, stretching from Lamprey Creek on the south to Glasgow on the north, a distance of nearly 30 miles, and having a width of about 5 miles. It contains a number of more or less active mines, of which the Beaver Hill is the largest. The structure of the southern portion of this basin about Riverton and Beaver Hill is apparently simple, but from a

[1] Diller, J. S., and Pishel, M. A., Preliminary report on the Coos Bay coal field, Oreg.: U. S. Geol. Survey Bull. 431, pp. 190–228, 1911.

point near Coaledo northeastward to Stock Slough minor folds and faults are common and the structure is complex. The average dip of the strata in the whole basin, however, is only about 26°. Near Marshfield the Mill Slough fault cuts off the north end of the Westport arch and drops the middle portion of the north end of the coal field.

The South Slough basin embraces the country about South Slough from a point near its head to the mouth of Coos Bay, where it passes beneath the sea. The strata of this basin are much compressed. Their average dip is about 56°, but locally they are vertical or overturned. No coal is shipped from this basin, although it is taken out for generating power in the immediate vicinity.

The Newport basin is a small syncline in the fork of the Westport arch. It contains the Newport bed of coal, which is the most important coal bed of the region and has been recognized throughout the greater portion of the South Slough and Beaver Slough basins. At Libby this coal has been mined for many years. The north end of the Newport basin is cut off by the Mill Slough fault, in which the downthrow is on the north side. Beyond the fault lie the Flanagan, North Bend, and Empire basins, which are even smaller than the Newport basin.

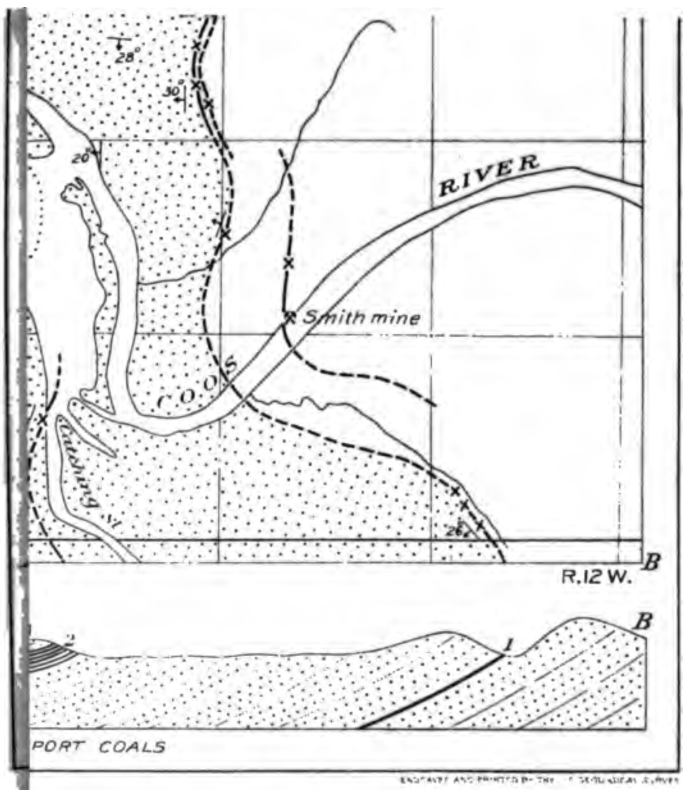
Though the principal coal areas north of Coquille River are shown on the map (fig. 22, p. 131), details concerning the structure and composition of the coal beds will be omitted. That information is given in Bulletin 431 of the United States Geological Survey.

The original coal supply of the Coos Bay field has been estimated by M. R. Campbell as 1,000,000,000 short tons.

NORTHERN PART OF THE FIELD.

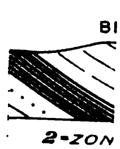
The northern part of the Coos Bay coal field surrounds Coos Bay and in this part of the field the places of shipment are Marshfield, Empire, and North Bend.

Much of the region is underlain by coal, but throughout the larger portion of the areas the coal is more than 2,000 feet beneath the surface. On the map (Pl. IX) only those parts which have coal within 2,000 feet of the surface are indicated. They occur along the eastern and southern borders of Coos Bay, as well as in the North Bend, Empire, and Flanagan basins and portions of the Newport and South Slough basins. The forest cover in this area is so dense as to conceal completely the soft rocks of the coal measures and render prospecting especially difficult. It is possible that future investigations may prove that the areas of coal within 2,000 feet of the surface are much larger than those here shown. The Flanagan and North Bend basins may be continuous, but no coal has yet been found between them.



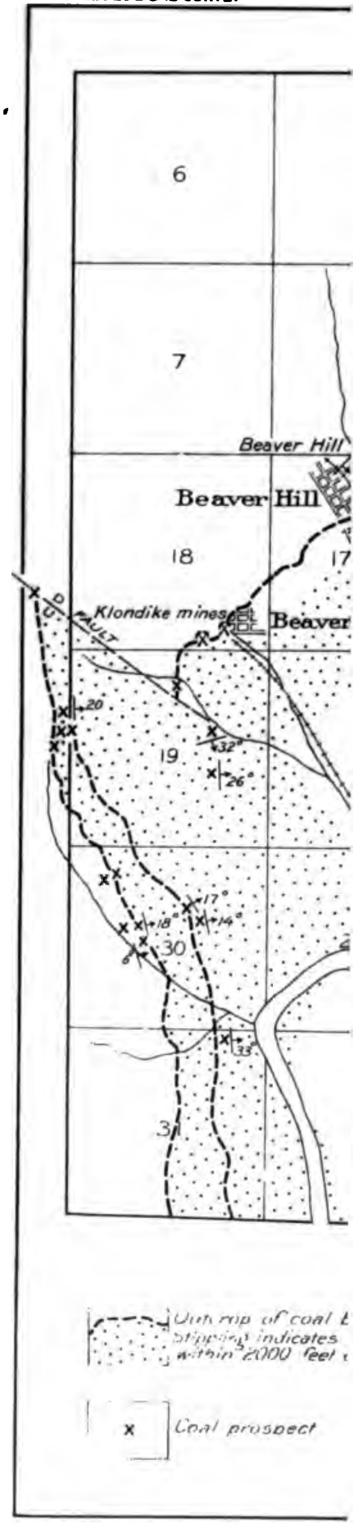
House Doc. ; 63d Cong., 2d Sess.

EGON



AL FIEI

U. S. GEOLOGICAL SURVEY



MAP OF

The general structure of the Coos Bay coal field, as already explained, renders intelligible without further detail the structure of the coal measures.

MIDDLE PART OF THE FIELD.

In the middle part of the Coos Bay coal field, where the coal field is widest, most of the important structural features are well developed and are shown in Plate X. South Slough basin contains the coal on the west side and the Newport basin in the middle along the northern border. On the east the coal lies in the Beaver Slough basin bordered on the southeast by the compressed basin about Sumner. The relations of the basins are best shown by the section at the bottom of Plate X. The last two basins named are separated by an overturned and faulted arch, which apparently complicates the structure of that region.

The zone of the Sevenmile coal is brought to the surface by the Westport arch. All the coal found in the four basins appears to belong to the Newport zone.

The mine at Libby has been worked more or less vigorously for many years. A branch railroad runs to the Smith & Power mine.

The South Fork basin is widest and deepest, and much of the coal is probably below the depth at which it could be profitably mined.

SOUTHERN PART OF THE FIELD.

The resurvey of the southern portion of the Coos Bay coal field has been completed only as far as the southern limit of T. 27 S., R. 13 W., a map of which is shown in Plate XI. This township contains the Beaver Hill and Peart mines, between which, in Beaver Slough basin, occurs one of the largest bodies of coal in the Coos Bay coal field.

The depth of the Beaver Slough basin is not definitely known. Borings have been made in the middle portion by private parties, but the data are not available for publication.

Aside from the alluvium, the Arago is the only geologic formation found in T. 27 S., R. 13 W. From 7,000 to 8,000 feet of strata are exposed here, made up largely of sandstone, shaly sandstone, and some shale, all of which are of a grayish-green to a yellowish-green color and comparatively soft. Coal is found in two zones.

A large syncline whose axis runs northeast and southwest is the most important structural feature in this portion of the coal field. The small irregular anticline in the northeast quarter of the township splits the large syncline into two small ones. Wherever mining is carried on to any extent small faults are found. As the rocks are made up largely of sandstone and considerable folding has taken

place it is only natural that some faulting should occur. No fault detrimental to mining has yet been found, but the large offset of the Newport bed in sec. 19 indicates either a good-sized fault or a very sharp fold. Some more detailed work should be done to ascertain the true conditions.

ECKLEY COAL FIELD.

In the Port Orford quadrangle, 45 miles south of Coos Bay, traces of coal have been found at a number of localities near Eckley (see fig. 22, p. 131) in an isolated patch of Eocene sediments. These are described in the Port Orford folio, where the coal field is outlined as having an area less than a score of square miles in extent. Although there are several small coal beds, chiefly carbonaceous shale, in the sandstone of the Eckley field, most of the carbonaceous material occurs at or near the bottom of the sandstone in irregular bunches or layers of small extent. Aside from the difficulties of transportation from this isolated mountain region these fairly extensive prospects do not warrant the expectation of finding in the Eckley field coal that would be worth mining.

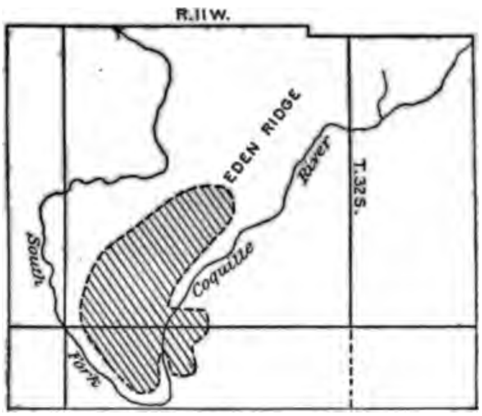


FIGURE 24.—Map showing by shading location of Eden coal field.

EDEN COAL FIELD.

Eden coal field is in the Siskiyou National Forest and has attracted much attention on account of the large number of contested coal claims it contains. It is confined mainly to Eden Ridge, which runs northeast and southwest across T. 32 S., R. 11 W., and, as shown in figure 24, lies for the most part within a great bend of the South Fork of Coquille River. The slopes of the coal field are steep and in many places bold cliffs face the river.

A large-scale map (fig. 25) showing in part the relation of the approximate boundaries of the coal field to the section lines is based wholly on the recent work of C. E. Lesher.[1] The area of the field, including a small portion on the southeast side of the bend, was considered in 1907 to be about 3 square miles but Mr. Lesher's work in 1913 has shown it to be much larger.

[1] Since my examination of the field was made it has been extensively prospected by the claimants. In 1912, Mr. M. R. Campbell spent several days in the Eden coal field and in 1913, Mr. C. E. Lesher spent six weeks there mapping it in great detail. These later researches have enlarged the field by the discovery of lower beds of more valuable coal.

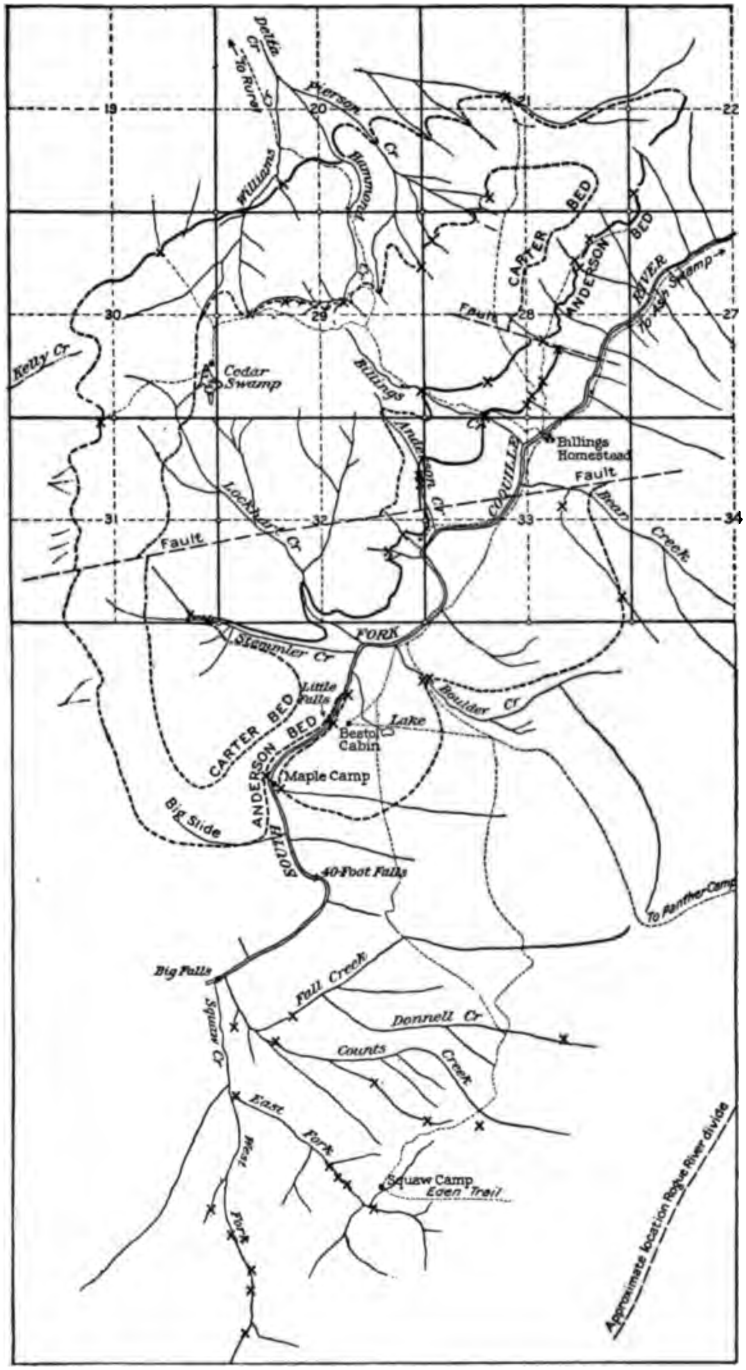


FIGURE 25.—Map of Eden coal field showing prospects (×) and outcrop of Carter and Anderson coal beds (solid line, determined outcrop; dashed line, probable location of outcrop). By C. E. Lesher.

The shallow synclinal structure of Eden Ridge is roughly outlined in the cross section shown in figure 26.

Only two coal beds in this field were in 1907 considered important, the Carter and the Anderson. Both are now known to extend through the hill.

One of the best exposures of the Anderson coal is in the SE. ¼ sec. 28 and shows the following section:

Section of Anderson coal in the SE. ¼ sec. 28, T. 32 S., R. 11 W.

	Ft.	in.
Shaly sandstone roof.		
Coal, somewhat shaly, banded	3	
Parting, indistinct sandy clay		1–2
Coal and shaly coal interbanded	3	
Clay		3
Sandstone floor.		

The coal exposed in a bluff is wet and thus protected from weathering. For the purpose of testing its value, a sample was taken of the

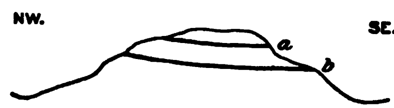


FIGURE 26.—Generalized section of Eden coal field. *a*, Carter coal; *b*, Anderson coal.

best 5 feet of continuous section across the bed. This sample was sent to the laboratory of the Carnegie Technical Schools in Pittsburgh, Pa., where a proximate analysis and calorific test resulted as follows:

Analysis of air-dried sample of best 5 feet of Anderson coal.

Air-drying loss	2.80
Moisture	3.91
Volatile matter	32.21
Fixed carbon	31.34
Ash	32.54
Sulphur	1.91
Calorific value in British thermal units	8,699

The Carter coal in sec. 29, on the northwest slope of Eden Ridge, has the following section:

Section of Carter coal in sec. 29, T. 32 S., R. 11 W.

	Ft.	in.
Shaly sandstone (?) roof.		
Shaly coal, variable, banded	4	9
Coal, some good, but mostly bony	2	6
Shaly sandstone floor.		

The material exposed in an open cut is fresh, and some of the best-looking lustrous coal of the region occurs in the lower portion of the bed at this exposure. A sample of a continuous section of the best 5 feet of coal at this outcrop was taken for analysis and calorific test.

As the bed contains no prominent parting which could be picked o[illegible] in mining, nothing was rejected from the sample. The results of t[illegible] analysis and test in the laboratory of the Carnegie Technical Schoo[illegible] at Pittsburgh, Pa., are as follows:

Analysis of air-dried sample of best 5 feet of Carter coal.

Air-drying loss	2.40
Moisture	5.08
Volatile matter	27.25
Fixed carbon	40.51
Ash	27.16
Sulphur	.49
Calorific value in British thermal units	9,074

Owing to environment and composition, especially the high pe[illegible] centage of ash, the Anderson and Carter coals were in 1907 n[illegible] considered workable for transportation, but their calorific value [illegible] such as to suggest the possibility of using them on the ground as [illegible] source of power in a gas-producer engine. The later more detaile[illegible] researches of Mr. Campbell in 1912 and Mr. Lesher in 1913 ha[illegible] enabled them to give a more favorable report on the Eden coal fiel[illegible]

LOOKINGGLASS AND CAMAS VALLEY FIELDS.

Small outcrops of coal have been known for many years in t[illegible] vicinity of Lookingglass, about 8 miles west of Roseburg, but n[illegible] until 1909 was any considerable attempt made at development. [illegible] that time a tunnel was run in on a coal bed that showed 2 feet of goo[illegible] coal with marked block cleavage. The bed is overlain by a fir[illegible] carbonaceous coaly shale that will make a fair roof and underlain b[illegible] a dark-gray slippery clay that is likely to give trouble in minin[illegible] The coal was used for a time in a smithy and promised so well f[illegible] other purposes that the prospect was sold, but operations soon cease[illegible] As far as known the coal is of small extent and can not be mine[illegible] successfully on any considerable scale.

Similar outcrops have been found at a number of points in th[illegible] region, especially near Camas Valley. They were prospected by t[illegible] same promoting company in 1909 with much enthusiasm, but as f[illegible] as reported no large bodies of coal have been opened up.

COAL FIELD ON THE NORTH FORK OF THE UMPQUA.

Small beds of coal have been found on the North Fork of t[illegible] Umpqua, also on Little River and Cavatt Creek, as well as Coal Cree[illegible] which flows into the Calapooya. All these localities are near t[illegible] eastern border of the Roseburg quadrangle and indicate the accum[illegible] lation of vegetation along the shores of the ancient Eocene se[illegible] None of the beds are of considerable economic importance. It [illegible]

said that a wagonload was taken out on the North Fork and hauled to Roseburg for trial, but its quality did not prove to be especially good. Several tons have been removed from an opening near the mouth of Cavatt Creek, for blacksmithing, but the supply is limited. An analysis of the coal from this locality shows its composition to be as follows:

Analysis of coal near the mouth of Cavatt Creek.

Moisture	4.64
Volatile matter	38.54
Fixed carbon	39.00
Ash	17.80
Sulphur	.44
	100.42

Other prospects for coal have been made between the Coast and the Cascade ranges by the Southern Pacific Co. near Comstock, north of Drain, but very little coal was discovered.

ROGUE RIVER VALLEY COAL FIELD.

Of the coal fields in southwest Oregon the one in Rogue River valley (see fig. 22, p. 131) is the most conveniently located with reference to the Southern Pacific Railroad. A number of years ago this coal field was prospected by the Southern Pacific Co., but coal production did not follow immediately. Since then there has been a great deal of prospecting, especially in the vicinity of Medford and Ashland. As a result the field is known to be about 80 miles in length and only a few miles in width, dipping eastward beneath the Cascade Range. Parts of it are described in detail elsewhere.[1]

Considerable coal has been mined and sold for local use, but the large percentage of ash, as shown in the following analysis, impairs it for domestic purposes:

Analysis of sample of coal (No. 5346) obtained near Medford, Oreg.

[F. M. Stanton, chemist in charge, U. S. Geol. Survey fuel-testing plant.]

	As received.	Air dried.
Loss of moisture on air drying		2.00
Moisture	11.30	9.49
Volatile matter	23.39	23.87
Fixed carbon	31.89	32.54
Ash	33.42	34.10
Sulphur	1.16	1.18
Calories	4,183	4,268
British thermal units	7,529	7,683

[1] Diller, J. S., The Rogue River valley coal field, Oreg.: U. S. Geol. Survey Bull. 341, pp. 401–405, 1909.

For the present the coal beds from Ager, in California, to Evans Creek, in Oregon, are only of local interest as a source of fuel, but detailed examinations in the future may show these coals to be more extensive than they are now supposed. If so, they may become, with the improvement of gas producers, important sources of power.

GEOLOGICAL SURVEY PUBLICATIONS ON SOUTHWESTERN OREGON.

[The asterisk (*) indicates publications out of stock.]

ANNUAL REPORTS.

*Fourteenth, Part II, 1894. 597 pp., 74 pls. Includes: (*g*) Tertiary revolution in the topography of the Pacific Coast, by J. S. Diller. 38 pp., 8 pls.

*Seventeenth, Part I, 1896. 1076 pp., 67 pls. Includes: (*c*) A geological reconnaissance in northwestern Oregon, by J. S. Diller. 80 pp., 13 pls.

*Nineteenth, Part III, 1899. 785 pp., 99 pls. Includes: (*c*) The Coos Bay coal field Oreg., by J. S. Diller, 68 pp., 13 pls.

*Twentieth, Part III, 1900. 595 pp., 78 pls. Includes: (*a*) The Bohemia mining region of western Oregon, with notes on the Blue River mining region and on the structure and age of the Cascade Range, by J. S. Diller, accompanied by a report on fossil plants associated with the lavas of the Cascade Range, by F. H. Knowlton. 58 pp., 6 pls.

*Twenty-second, Part II, 1901. 888 pp., 82 pls. Includes: (*e*) The gold belt of the Blue Mountains of Oregon, by Waldemar Lindgren, 226 pp., 16 pls.

*Twenty-second, Part III, 1902. 763 pp., 53 pls. Includes: (*k*) The Pacific coast coal fields, by Geo. Otis Smith. 40 pp., 4 pls.

MONOGRAPH.

XLVIII. Status of the Mesozoic floras of the United States (second paper), by L. F. Ward with the collaboration of W. M. Fontaine, Arthur Bibbins, and G. R. Wieland. In two parts. 1905. Part I, 66 pp.; Part II, 119 pls. Price $2.25.

PROFESSIONAL PAPER.

*59. Contributions to the Tertiary paleontology of the Pacific Coast; I, The Miocene of Astoria and Coos Bay, Oreg., by W. H. Dall. 1908. 270 pp., 23 pls.

BULLETINS.

*193. The geological relations and distribution of platinum and associated metals, by J. F. Kemp. 1902. 95 pp., 6 pls. (Platinum in California and Oregon, pp. 51-56.)

*196. Topographic development of the Klamath Mountains, by J. S. Diller. 1902. 69 pp., 13 pls.

*315. Contributions to economic geology, 1906, Part I. 1907. 505 pp., 4 pls. Includes: (*c*) Nickel deposits of Nickel Mountain, Oreg., by G. F. Kay, 8 pp.

*340. Contributions to economic geology, 1907, Part I. 1908. 482 pp., 6 pls. Includes: (*a*) The mines of the Riddles quadrangle, Oreg., by J. S. Diller and G. F. Kay, 19 pp.

341. Contributions to economic geology, 1907, Part II. 1909. 444 pp., 25 pls. Includes: (*c*) The Rogue River valley coal field, Oreg., by J. S. Diller, 5 pp.

*380. Contributions to economic geology, 1908, Part I. 1909. 406 pp., 2 pls. Includes: (*a*) Mineral resources of the Grants Pass quadrangle and bordering districts, Oreg., by J. S. Diller and G. F. Kay; Notes on the Bohemia mining district, Oreg., by D. F. MacDonald. 37 pp., 1 pl.

387. Structural materials in parts of Oregon and Washington, by N. H. Darton. 1909. 36 pp., 9 pls.

431. Contributions to economic geology, 1909, Part II. 1911. 254 pp., 12 pls. Includes: (*b*) Preliminary report on the Coos Bay coal field, Oreg., by J. S. Diller and M. A. Pishel, 37 pp.

WATER-SUPPLY PAPERS.

214. Surface water supply of the north Pacific coast drainage, 1906, by J. C. Stevens, Robert Follansbee, and E. C. La Rue. 1907. 208 pp., 3 pls.

252. Surface water supply of the north Pacific coast, 1907–8, by J. C. Stevens and F. F. Henshaw. 1910. 397 pp., 9 pls.

272. Surface water supply of the north Pacific coast, 1909, by J. C. Stevens and F. F. Henshaw, 1911. 521 pp., 8 pls.

292. Surface water supply of the north Pacific coast, 1910, by F. F. Henshaw, G. C. Baldwin, and G. C. Stevens. 1913. 685 pp., 3 pls.

GEOLOGIC FOLIOS.

[Each folio contains topographic and geologic maps, with text describing the geology and mineral resources of the quadrangle.]

*Roseburg folio (No. 49), by J. S. Diller. 1898.

*Coos Bay folio (No. 73), by J. S. Diller. 1901.

Port Orford folio (No. 89), by J. S. Diller. 1903. Price 5 cents.

TOPOGRAPHIC SHEETS.

[Relief shown by contours. Price 10 cents each or 6 cents each for 50 or more maps.]

Ashland and Klamath sheets. Scale, 1: 250,000.

Roseburg, Coos Bay, Port Orford, Riddles and Grants Pass sheets. Scale, 1: 125,000.

Eugene and Crater Lake National Park sheets. Scale, 1: 62,500. (The Crater Lake National Park sheet has an account of the geology with illustrations of Crater Lake.)

INDEX.

A.

Page.

Acknowledgments — 9
Almeda mine, character of ore in — 75–79
  description of — 72–81
  origin of ore in — 79–80
  plan and longitudinal section of, figure showing — 73
  smelter of — 80–81
Alta mine, description of — 70
Althouse Creek, mining on — 118
Anderson, Frank M., acknowledgments to — 10
  on the Forty-nine mines of the Ashland region, Oreg. — 90–93
Anderson, G. E., prospect, description of — 63
Anderson, H. V., acknowledgments to — 10
Anderson & Wilson mine, description of — 122–123
Applegate district, placers in — 116–117
Arago group of claims, description of — 51
Ashland region, Forty-nine mines of — 90–93
Augite andesite, occurrence of — 21

B.

Baby Foot Creek, prospects on — 65
Baby mine, description of — 34–35
Bacon, W. S., acknowledgments to — 9
Baily Creek, mines near — 51
Bandon district, beach mining in — 125–126
Barlow, C. L., acknowledgments to — 9
Bates, P. H., analyses by — 16
Battle Bar mine, description of — 115
Beach placers, discovery and nature of — 125
Beauty claim, description of — 67
Benson mine, description of — 117
Big Four mine, description of — 111–112
Black Bear mine, description of — 56–57
Black Bear claim, description of — 65
Black Gold Channel mine, description of — 108–109
Black Hawk property, description of — 57
Blanchard Gulch, claims on — 57, 58
Blanco mine, description of — 126
Blue Bell prospect, description of — 55
Blue River mining region, description of — 25–26
Bohemia mining region, description of — 26–30
  development in — 28–29
  map showing — 26
Bowden, W. S., acknowledgments to — 9
Bowden prospects, description of — 69
Braden mine, description of — 39–41
Brantner mine, description of — 117

Page.

Briggs Creek, auriferous gravel on — 97–98, 101–102
  mining on — 124
Brown, Will Q., acknowledgments to — 9
Buckeye mine, description of — 61
Buffalo group of claims, description of — 55–56
Butcher Gulch, mining on — 119–120

C.

Calumet mine, description of — 63–64, 85
Camas Valley coal field, location and character of — 139
Canyon Creek, mines on — 68, 69, 121–122
Canyon Creek Consolidated Gold mines, description of — 68–69
Cape Blanco district, beach mining in — 126–127
Carlton group of claims, description of — 60
Casey prospect, description of — 64
Cavatt Creek, coal from, analysis of — 140
Champlin mine, description of — 107–108
Chatty mine, description of — 67–68
Chetco Copper Co. mine, description of — 84
Chetco River, mine on — 84
Chieftain Gulch, mine on — 60
Cinnabar, occurrence of — 129
Coal, analyses of — 138, 139, 140
  nature and distribution of — 130
  production of — 23, 130
Coal fields of southwest Oregon, map showing — 131
Coast Range, even crest of, plate showing — 12
Coffee Creek, placers on — 103
Cold Spring Copper mine, description of — 60
Collier Creek prospect, description of — 85–86
Columbia mine, description of — 104–105
Cook mine, description of — 109
Coos Bay coal field, map of — 132
  map of middle part of — 134
  map of north part of — 134
  map of T. 27 S., R. 13 W — 134
  situation of — 130–133
  stratigraphy of — 133
  structure of — 133–136
Copper, distribution of — 72
  mining of — 60
  occurrence of — 29–30, 72
  production of — 71, 88
Copper ore, analyses of — 76
Corporal G mine, description of — 37

Page.
Cottonwood district, Cal., Cretaceous gravel in 89-90
Cottonwood Valley, Cal., geologic section across, figure showing 90
Cow Boy mine, development in 83
Cow Creek, mines near 37, 86, 103
Coyote Creek, placers on 104
Cretaceous conglomerate in Forty-nine mine, plate showing 92
nature and occurrence of 88-90
of Waldo, description of 93-95
Cretaceous islands, shore line of, figure showing 89
Cretaceous rocks, nature and distribution of 18

D.

Dacite porphyry, occurrence of 21
Daisy mine, description of 35-36
Days Gulch, prospects near 66, 67
Dean and Corliss mine, description of 113
Deep Gravel mine, description of 119-120
Deer Lick, claims on 50
Dikes, rocks forming 21
Dredging, Charles Janin on 107-108
Drew Creek, prospect on 87-88

E.

Eckis mine, description of 127
Eckley coal field, description of 136
Eden coal field, analyses of samples from 138, 139
description of 136-139
generalized section of, figure showing 138
maps showing 136, 137
Elwilda mine, description of 52
Eureka mine, description of 62-63
Evans Creek district, placers in 106

F.

Fall Creek, claims near 65, 84
Faults, in the Baby mine 35
Ferris Gulch, mining on 116
Fiddlers Gulch, claims on 68
Fidelity group of claims, description of 70-71
Field work, record of 9
Flanagan & Emerson mine, description of 112
Foots Creek, mines on 43, 107-109
Forest Creek, mining on 110-111
Forty-nine mine, cretaceous conglomerate in, plate showing 92
Free and Easy mine, description of 71

G.

Galice Creek, auriferous gravel on 97, 98-101
mines on 54, 58, 59, 60

Page.
Galice district, placers in 112-113
Galice-Kerby-Waldo region, general features of 46-48
geologic reconnaissance map of 46
Galls Creek, mine near 43
placers on 106
Geography of the region 11-14
Geologic folios published, map showing 10
Geology of the region 14-22
Glen Ditch mine, description of 109
Gold, occurrence of 23-25
production of 22-23, 24, 28-29, 46-47
Gold Basin, gravels of, nature and situation of 95-96
Gold Bug mine, description of 52-53
Golden Dream mine, description of 65
Golden Pheasant group of claims, description of 58
Golden Wedge mine, description of 51
Gold Hill district, placers in 106
Gold Hill pocket, description of 45-46
Gold lode mines 23-71
Gold Plate property, description of 59
Gold-quartz mines in Grants Pass quadrangle, map showing 40
Gold Ridge prospects, description of 66-67
Granite Hill mine, description of 42
Granodiorite, nature of 20-21
Grants Pass quadrangle, gold-quartz mines in, map showing 40
limestone outcrops in, map showing 16
location of 39
smaller mines and prospects in 45
Grave Creek, placers on 104-105
Gravels, auriferous, distribution of, map showing 96
auriferous, formation of 14
of Cretaceous age, nature and occurrence of 88-90
of first cycle of erosion, description of 95-97
of Gold Basin, nature and situation of 95-96
of second cycle of erosion, description of 97-102
near York Butte, nature and situation of 96-97
of third cycle of erosion, description of 102
Greenback mine, description of 31-34
Green Mountain copper prospect, description of 86-87
Greenstone, gold lodes in 37
Greenstones, nature of 19-20

H.

Harvey, J. R., cited 100-101
Harvey mine, old-channel bedrock in, profile of, figure showing 101
Higgins mine, description of 64-65

Page.
High Gravel mine, description of 94–95
Hogue, P. F., acknowledgments to 9
Holdsworth, P. H., acknowledgments to 9, 73
cited 76–77, 78–79, 80
Hoover Gulch, claim near 65, 66
Horsehead mine, description of 117–118
Horseshoe Bar mine, description of 114
Howard Creek, claims on 54, 55
Hubbert mine, description of 52
Humbug Creek, placers on 116
Hustis and Anderson claims, description of 65

I.

Ida mine, location of 42
Igneous rocks, nature and distribution of 19–21
Illinois River, mines near 63, 94–95, 122–124
Iridium, production of 120, 127
Iron Mountain, even crest of, plate showing 13

J.

Jack Creek, mining on 35, 105
Jacksonville district, placers in 109–111
Janin, Charles, cited 107–108
Jewett mine, description of 44–45
Joe Smith Gulch, mining on 119–120
Johnson Creek, mines on 30, 102–103
Johnston mine, description of 116–117
Jones, Fayette A., acknowledgments to 9
Joseph Ball mine, description of 87
Josephine County, gold production in 46–47
Josephine Creek, cross-section profile of, figure showing 121
mines on 47, 70, 120–122
Jumpoff Joe Creek, placers on 105
Jurassic rocks, generalized section across, figure showing 18
nature and distribution of 17–18

K.

Kane Creek, mining on 106
Kay, G. F., acknowledgments to 10, 31, 39, 81
cited 87, 94–95
Keeler Creek, mine on 116
Keystone group of claims, description of 53
Klamath Mountains, even crest of, plate showing 14
general relations of 11–12
Klamath Mountains and adjacent ranges, geologic map of 11
Klamath peneplain, age of 95
formation of 13–14
gravel beds in 95–97
plate showing 14
Kramer prospect, description of 52

L.

Page.
Lance mine, description of 109
Layton mine, description of 116
Lead, production of 88
Legal Tender group of claims, description of 54
Lightning Gulch, prospects on 69
Liljegran, E. W., acknowledgments to 9, 40, 45
Limestone, outcrops of, in Grants Pass quadrangle, map showing 16
Paleozoic, age of 15–16
composition of 16–17
distribution of 15
Limpey Creek, claims near 60–61
Logan, Simmons & Cameron mine, cross section of, figure showing 94
description of 120
section of tailrace of, figure showing 94
Lookingglass coal field, location and character of 139
Lost Flat mine, description of 60
Lucky Bart mine, description of 38
Lyttle mine, development in 83

M.

Mabel mine, development in 83
MacDonald, D. F., on the Bohemia mining district 27–30
Maid of the Mist mine, description of 44
Mammoth, bones of, found near Sterling Creek 110
Mangum, C. L., acknowledgments to 9
Martha mine, description of 34
Mayflower property, description of 56
Medford, analysis of coal from 140
Medford district, location of 39
Mica schist, nature and distribution of 14
Mike Gulch, claims near 66
Miller Creek, mines on 65, 118
Miller and Bacon prospects, description of 65–66
Miller & Savage mine, description of 118
Mineral production of the region 22–23
Mood mine, description of 68
Morphy, C. M., acknowledgements to 42
Mountain Lion mine, description of 43
Mount Bolivar region, mines in 58
Mount Pitt mine, description of 36
Mount Reuben, mines near, description of 52–53
Myrtle Creek, mines on 31, 103

N.

Nickel, occurrence of 84, 85, 129–130
Neil mine, description of 68
Nesbit group of claims, description of 57

O.

Oak mine, description of 87
Olalla Creek, placers on 103

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 547

RECONNAISSANCE

OF THE

GRANDFIELD DISTRICT, OKLAHOMA

BY

MALCOLM J. MUNN

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

CONTENTS.

	Page.
Introduction	5
Location of district	5
Character and purpose of the work	5
Acknowledgments	6
Drainage and topography	6
Stratigraphy	7
Rocks not exposed in the district	7
Permian rocks	7
Pennsylvanian and older rocks	8
Rocks exposed in the district	17
Age and general character	17
Carboniferous system (Permian series)	18
Thickness and subdivisions	18
Wichita formation	18
Character and occurrence	18
Auger conglomerate lentil	23
Tertiary or Quaternary system	28
Grandfield conglomerate	28
Quaternary system	30
Gravels	30
Alluvium	30
Dune sand and soil	31
Structure	31
Devol anticline	31
Deep Red syncline	32
Minor anticlines	33
Local synclines	34
Detailed stratigraphy and structure of exposed rocks, by townships	34
T. 5 S., R. 16 W	34
T. 4 S., R. 16 W	35
T. 3 S., R. 16 W	37
T. 3 S., R. 15 W	37
T. 4 S., R. 15 W	41
T. 5 S., R. 15 W	45
T. 5 S., R. 14 W	45
T. 4 S., R. 14 W	46
T. 3 S., R. 14 W	51
T. 3 S., R. 13 W	55
T. 4 S., R. 13 W	59
T. 5 S., R. 13 W	63
T. 5 S., R. 12 W	65
T. 4 S., R. 12 W	68
T. 3 S., R. 12 W	70
T. 4 S., R. 11 W	71
T. 5 S., R. 11 W	73
Suggestions to prospectors	74
Index	85

ILLUSTRATIONS.

		Page.
PLATE I.	Geologic sketch map of Oklahoma and northern Texas	6
II.	*A*, Bed of Red River at low water, from adjacent bluff in sec. 32, T. 5 S., R. 12 W.; *B*, General view of the surface in the Grandfield district, showing distant "breaks"; *C*, Near view of "breaks" in west side of SW. ¼ sec. 21, T. 3 S., R. 15 W	8
III.	Sections of deep wells in northern Texas and southern Oklahoma, with sketch map showing locations	In pocket.
IV.	Reconnaissance geologic map of the Grandfield district, showing structure	In pocket.
V.	North bluff of Red River in NE. ¼ sec. 31, T. 5 S., R. 12 W., showing westward dip of Permian rocks; *B*, South bluff of Red River in T. 5 S., R. 16 W., showing westward dip of Permian sandstone; *C*, Eastern part of bluff shown in *B*	34

RECONNAISSANCE OF THE GRANDFIELD DISTRICT, OKLAHOMA.

By M. J. MUNN.

INTRODUCTION.

LOCATION OF THE DISTRICT.

The Grandfield district as arbitrarily outlined in this report embraces about 360 square miles in southern Oklahoma, including the southeastern part of Tillman County and the southwestern part of Cotton County, as shown on Plate I. This district, which is bounded on the south by Red River, includes those parts of Tps. 3, 4, and 5, Rs. 12, 13, 14, and 15 W., that lie in Oklahoma; that part of T. 4 S., R. 11 W., that lies south of Deep Red Run; the west half of the area in T. 5 S., R. 11 W., that lies north of Red River; the southeast quarter of T. 3 S., the east half of T. 4 S., and the portion of T. 5 S., R. 16 W., that lies north of Red River. The district is named from Grandfield, the largest town within it, which stands near its center.

CHARACTER AND PURPOSE OF THE WORK.

This report discusses the general geologic conditions in this district, especially those that furnish a clue to the possible location of any oil and gas pools that may be in it. The field work for the report was begun by the writer about October 10, and continued until December 22, 1912. From about November 17 to December 22 he was assisted by Mr. Jerry B. Newby, who ran spirit-level lines over a portion of the district to determine the structure of certain outcropping beds. The work was done under a cooperative agreement between the United States Geological Survey and the Geological Survey of Oklahoma by which the latter provided funds to the amount of $500 toward paying the cost of field work and the former paid about $200 of the field expenses and all office expenses and cost of publication.

This territory was selected for reconnaissance geologic examination because the general geologic conditions in it are the same as those in the adjacent portion of northern Texas, which contains the Petrolia, Electra, and Burkburnett oil and gas fields, and because it was hoped that geologic work in this district in advance of drilling

might enable oil and gas prospectors to place their test wells most favorably and so avoid losses involved in drilling dry holes and at the same time obtain the best tests for the presence of oil and gas in paying quantities.

The time spent in field work was so short that the survey can be considered only a reconnaissance, during which detailed stratigraphic study of the outcropping rocks was impracticable. The principal object of the stratigraphic study was to find some widely exposed bed or series of beds having features so persistent that it might be used as a key stratum or horizon for determining roughly the structure of the Permian rocks of the district. The writer began field work in the vicinity of Grandfield, where outcrops of rocks are scarce and those that occur embrace only a few feet of the geologic section. The preliminary examination in search of a key stratum or horizon covered about 200 square miles around Grandfield, in Tps. 2, 3, 4, and 5 S., Rs. 13, 14, 15, and 16 W. This selection of territory for preliminary work was fortunate in the fact that the most easily identified series of outcropping beds are exposed there, but it was also in a measure unfortunate because the finest outcrops occur in the bluffs of Red River, near and at the extreme eastern edge of the area examined. These important outcrops on Red River were not discovered until the last few days of the field work, when time was not available to make a detailed stratigraphic study of them and a thorough search for fossils.

ACKNOWLEDGMENTS.

The writer is indebted to Mr. D. W. Ohern, State geologist of Oklahoma, for suggestions regarding field work. A very valuable list of bench marks, which shows the elevation above sea level of points along the Wichita Falls & Northwestern Railway and on which the net of spirit levels is based, was kindly furnished to the writer by Mr. J. F. Montgomery, division engineer of the railway. The writer is also indebted to many citizens of the district for assistance rendered and courtesies shown during the progress of the field work.

DRAINAGE AND TOPOGRAPHY.

The Grandfield district is drained by Red River and Deep Red Run, a tributary of Cache Creek, which empties into Red River from the north. Red River has an average fall across this district of 3½ to 4½ feet a mile. It flows in a relatively narrow flood plain, ranging in width from 1 to 1½ miles, bounded on both sides by bluffs covered by sand dunes and having a maximum elevation of about 175 feet above the river. The river bed is very broad in comparison with the width of its flood plain, being in most places from three-fourths of a mile to over a mile wide. At low water the river beds consist largely

of shifting sand, across which narrow, shallow streams meander. (See Pl. II, *C*.)

In contrast with Red River, Deep Red Run flows in a narrow channel, 20 to 60 feet wide and 20 to 30 feet deep, across a flat alluvial flood plain ranging in width from 1 to 1½ miles. The average fall of this stream is about 4½ feet to the mile.

The interstream area is a smooth, slightly undulating, treeless prairie, into which the smaller streams have cut very slightly except near their mouths. The notable features of the topography are (1) the broad, smooth surfaces, (2) a few low, round isolated hills adjacent to the divides, preserved by a capping of more resistant rocks, and (3) the many large "breaks" or washes (see Pl. II, *B* and *C*) similar in character to the well-known badlands of other portions of the West.

The "breaks" are of special importance to the geologist because they expose most of the beds of Permian rocks on which a map of the geologic structure of this area must be based. They consist of low bluffs, most of them roughly crescent shaped, from a few feet to half a mile in length (see Pl. II, *C*), and having heights ranging from 5 to 20 feet, though at places adjacent to the larger streams they are somewhat higher. These "breaks" have been formed chiefly by the direct action of rain falling on the steep, bare slopes of the very fine soft red clay of the "Red Beds." Most of them probably originated as small "potholes" dug out by running water of freshets pouring over small obstacles along the bottoms of "draws." "Breaks" thus started develop at all angles to the original drainage courses and some of them cut back across the crests of secondary ridges to points where water falling on the hillside, a few inches from the edge of the "break," flows directly away from it. Apparently one of the necessary conditions for the formation of a "break" is the presence of a more or less resistant layer above the soft red clay, so as to preserve a steep local slope. This resistant layer consists of a firm sod of grass at the surface or, very often, of thin beds of soft sandstone, limestone, or conglomerate embedded in the fine red clay that makes up the greater portion of the section exposed in this district.

STRATIGRAPHY.

ROCKS NOT EXPOSED IN THE DISTRICT.

PERMIAN ROCKS.

The lowest outcropping rocks in the Grandfield district are "Red Beds" of Permian age. Very few geologic facts regarding the age and character of the rocks which underlie those that outcrop have been derived directly from this district. The relatively small amount of data at hand pertaining to the rocks not exposed in this district

comes from the partial logs of three deep wells drilled for oil and gas in or near it, from logs of similar wells in the adjacent developed oil fields of northern Texas, and from outcrops of lower formations at more distant places in Oklahoma and Texas. The data indicate that the upper portion of unexposed beds is of Permian age and that this series is underlain by older Carboniferous beds of the Pennsylvanian series. The beds of the upper part of the Pennsylvanian are very similar to those of the lower part of the Permian in this district, so that the line of division between them can not be determined from the well records alone.

In Texas the contact between the Permian and the Pennsylvanian series comes to the surface south and southeast of the Grandfield district in a broad belt extending south-southwest from Clay and Montague counties, Tex., to the central part of the State. Along this belt the Wichita formation of the Permian appears to lie conformably upon the Cisco formation of the Pennsylvanian. This contact is also exposed at many places north and northeast of the Grandfield district in Oklahoma along the southern border of the Wichita and Arbuckle mountains, where the Permian "Red Beds," lying practically horizontal, rest unconformably on the sharply folded beds of the Pennsylvanian. The stratigraphic relation of these two great series of rocks in the large area that lies between the exposures of the Permian-Pennsylvanian contact and that includes the Grandfield district is not known. A brief study of each of them at the places nearest to the Grandfield district where they are best exposed may be of some value in determining the general character of the rocks underlying the beds exposed in this district.

PENNSYLVANIAN AND OLDER ROCKS.

In Clay, Montague, and Archer counties, Tex., where the rocks of the Pennsylvanian series are exposed, they are divided by Gordon [1] into the following formations, tabulated from top to bottom:

Section of Pennsylvanian formations in Wichita region, Tex

	Feet.
Cisco formation (clay, shale, conglomerate, and sandstone with some limestone and coal)	800
Canyon formation (alternating beds of limestone and clay, with some sandstone and conglomerate)	800
Strawn formation (alternating beds of sandstone and clay, with some conglomerate and shale; the lower 1,000 feet consists of blue and black clay locally containing beds of limestone, sandstone, or sandy shale, and a coal seam at the top	1,900
	3,500

[1] Gordon, C. H., Geology and underground waters of the Wichita region, north-central Texas: U. S. Geol. Survey Water-Supply Paper 317, p. 14, 1913.

A. BED OF RED RIVER AT LOW WATER, FROM ADJACENT BLUFF IN SEC. 32, T. 5 S., R. 12 W.

At medium stages the river is three-fourths to 1 mile wide and very shallow, flowing over a smooth, flat surface of sand and mud. At low water interlacing threads of water meander over this flat surface.

B. GENERAL VIEW OF THE SURFACE IN THE GRANDFIELD DISTRICT.

Showing distant "breaks" (below X marks).

C. NEAR VIEW OF "BREAKS" IN WEST SIDE OF SW. ¼ SEC. 21, T. 3 S., R. 15 W.

Showing character of the rain-cut bluffs and ridges in the fine red clay and the smooth, even slope formed by outwash from the "break."

Farther southwest in Texas the upper division of the Strawn is said [1] to reach a maximum thickness of 3,000 feet, the whole formation being about 4,000 feet thick.

Under the Strawn formation in the Colorado coal field of Texas lies the Bend series of the Texas Geological Survey, consisting principally of limestone and shale, which is of Pennsylvanian age in its upper part and of Mississippian age in its lower part. Gordon [2] gives the combined thickness of the Pennsylvanian and Mississippian series at about 7,000 feet in this region.

Along the southern borders of the Wichita and Arbuckle mountains in Oklahoma north and northeast of the Grandfield district the Pennsylvanian and older rocks, originally deposited in a relatively horizontal position, have since been elevated and thrown into steep folds by the great crustal uplifts that formed the Wichita and Arbuckle mountains. The old granite floor of the ancient sea in which the oldest sedimentary beds of Cambian age were laid down now constitutes the very resistant central cores of these mountains. Much of the strata which once arched over the old igneous rocks was removed by erosion before a later subsidence of the surface and encroachment of the sea allowed the deposition of the "Red Beds" in horizontal layers across the upturned edges of the older rocks. Since the "Red Beds" were deposited the region has been elevated to its present height, and streams have cut fairly deep valleys into them at many places adjacent to the mountains, where they were thin, exposing the older folded beds beneath. In the area indicated the Pennsylvanian rocks generally dip south or southwest beneath the less folded Permian beds. The southern extent of this unconformity between the Pennsylvanian and Permian is unknown, but, as noted above, the unconformity has not been observed in the next outcrops of these beds toward the south, in Texas.

The seemingly local character of the violent crustal movements which produced the Wichita and Arbuckle mountains suggests that the disturbance did not extend far south of a line joining these mountain areas and that the unconformity between the Pennsylvanian and Permian rocks dies out rapidly toward the south, terminating at a roughly east-west line in southern Oklahoma, beyond which there was seemingly continuous deposition throughout Pennsylvanian and Permian time.

No exposures of rocks older than Permian are known to occur for hundreds of miles west of the Grandfield district, and no data are available concerning the beds in that direction that will indicate the probable character of the rocks concealed in this district within

[1] Gordon, C. H., op. cit., p. 15.

[2] Gordon, C. H., The Wichita formation of northern Texas: Jour. Geology, vol. 19, No. 2, p. 116, 1911.

reach of the drill. The presence, however, of Pennsylvanian rocks beneath the "Red Beds" on three sides of the Grandfield district suggests strongly that the ancient seas in which the beds were deposited covered territory extending westward over many thousands of square miles and that the beds beneath the "Red Beds" in the Grandfield district are probably similar to those which are exposed around it. The following generalized section of the rocks underlying the "Red Beds" at their nearest outcrops in Oklahoma, south of Wichita and Arbuckle Mountains, tabulated in natural order, from top to bottom, is condensed from a previous report on the geology of these mountains.[1]

Generalized section of the Pennsylvanian and older formations outcropping adjacent to the Wichita and Arbuckle Mountains in Oklahoma.

Carboniferous system:

Unconformity.

Pennsylvanian series:

Sandstone, shale, and coal. North of the eastern part of the Arbuckle uplift the Pennsylvanian sediments overlying the Wapanucka limestone and the Franks conglomerate consist of sandstones, shales, and coals aggregating in thickness 10,000 or 11,000 feet. South of the Arbuckle Mountains these deposits are partly concealed by Cretaceous and younger beds and consist of shale, sandstone, thin beds of limestone, and some limestone conglomerate. The excessive folding in this area renders exact measurements of thickness of beds impossible.

Wapanucka limestone: Deposited contemporaneously with or just after the Frank conglomerate. Thickness increases to perhaps 400 feet eastward across the Arbuckle Mountain area in Oklahoma.

Frank conglomerate: Lies unconformably upon Mississipian beds. Greatest thickness, 500 feet.

Unconformity.

Mississipian series:

Glenn formation: Bluish shale, with thin brown sandstone and some thin limestone. Exposed only on north side of Arbuckle Mountains. Thickness, 1,000 to 3,000 feet.

Caney shale: Bluish toward top and contains small ironstone concretions. Basal part is black bituminous clay shale containing limestone and argillo-calcareous segregations. Total thickness, about 1,600 feet.

Sycamore limestone: Light bluish to yellow and probably argillaceous and massive; weathers into thin beds. Ranges in thickness from a few feet to nearly 200 feet and thickens toward the west from Arbuckle Mountains.

[1] Taff, J. A., and others, Preliminary report on the geology of the Arbuckle and Wichita Mountains: U. S. Geol. Survey Prof. Paper 31, 1904.

Devonian system:

Woodford chert: Black, bituminous, fissile shale, with round calcareous concretions; in lower part also contains at places beds of chert near base. Equivalent to the "Black shale" or Chattanooga (Ohio) shale of the Appalachian region. Average thickness, about 650 feet.

Siluro-Devonian rocks:

Hunton limestone:

Semicrystalline limestone, in places cherty, interstratified with some thin marly layers. Thickness, 30 feet.

Marly and calcareous clays with some hard limestone layers in lower part. Thickness, 170 to 190 feet.

Thick-bedded limestone, crystalline at base, with hard thin limestone above. At places at the base is an oolite, 4 to 5 feet thick, which is locally silicified.

Silurian system:

Sylvan shale: Greenish, homogeneous, massive shale at top with usually several feet of dark-blue to black calcareous, and bituminous shale at base. Ranges in thickness from 60 to 300 feet in the Arbuckle Mountains area, thickening toward the west.

Viola limestone:

Light colored, coarse textured, usually rough bedded; middle portion earthy. Thickness, 300 feet.

Limestone, white to light blue, generally thin bedded; weathers white. Thickness, 300 feet.

Limestone, light colored, coarse, and usually rough bedded. Thickness, 100 feet.

Ordovician system:

Simpson formation:

Limestone, thin, with interstratified green shales, 400 feet.

Sandstone, 90 feet.

Limestones and shales interstratified, 400 feet.

Sandstone, 100 to 200 feet.

Limestone, shaly, 195 feet.

Sandstone, 33 feet.

Limestone, thin bedded, and shale interstratified, 275 feet.

Shale, greenish, with few thin layers of limestone, 245 feet.

Limestone, granular, crystalline, in thin beds, 350 feet.

Limestone, thin, with shale and some thin layers of sandstone, 29 feet.

Sandstone, white to light brown, occurring locally, greatest thickness 100 feet.

Cambro-Ordovician rocks:

Arbuckle limestone: Includes all the upper Cambrian rocks and the Calciferous of the overlying Ordovicion. Except a few thin shaly strata and some siliceous and cherty beds it is composed entirely of light blue and white limestone and cream-colored to white crystalline dolomite. Its lower portion, which is upper Cambrian, is pink to yellow, hard, massive limestone and dolomite, which weathers brown to almost black and is 500 to 600 feet thick. This portion is succeeded above by limestones of Ordovician age, which become lighter toward their top. Total thickness of formation, 4,000 to 6,000 feet.

Middle Cambrian sediments: Generally thin-bedded siliceous limestone and shaly strata containing middle Cambrian fossils. Several hundred feet thick.

Reagan sandstone:

Thin-bedded and laminated sandstone, becoming calcareous in upper part. Thickness, 60 feet.

Coarse grit and sand with some clay and green sand in upper part, generally well stratified. Thickness, 370 feet.

Quartzites and arkose conglomerates. Thickness, 30 feet.

Pre-Cambrian: Granite and porphyry which formed the floor of the Cambrian Sea.

Fortunately we are not dependent entirely upon the character of the Pennsylvanian and older beds along their line of outcrop in surmising the character of the unexposed rocks in the Grandfield district. The development of the Petrolia, Electra, and Burkburnett oil fields in northern Texas has made available the logs of many deep wells in Clay and Wichita counties, Tex., a relatively short distance south of this district. In their excellent report on the geology of the oil and gas fields of Wichita and Clay counties, Tex., Udden and Phillips[1] have carefully correlated the unexposed rocks with those that outcrop in Texas southeast of these fields. Their report contains a detailed log and a description of samples from a test well drilled to a depth of 3,985 feet by the Producers Oil Co. on the Halsell farm, 6½ miles west and 1 mile south of Henrietta, Clay County, Tex. The value of this log and of the description of the samples of rock from the well justify reprinting them below.[2]

Log of Halsell well No. 1, drilled by the Producers Oil Co. west of Henrietta, Clay County, Tex., with description of samples of rock.

Driller's log.			Description of samples of rock.	
	Thickness.	Depth.	Depth at which sample was taken.	Geologist's notes.
	Feet.	*Feet.*	*Feet.*	
Red clay	65	65		
Salt water, sand	25	90		
Red rock	100	190		
Salt water, sand	30	220		
Red rock	245	465		
Salt water, sand	40	505		
Red rock	125	630		
Salt water, sand	30	660		
Red rock	112	772		
Water, sand	25	797		
Slate and red rock	20	817		
Sand, no water	24	841		
Red rock	49	891		
Sand	20	911		
Slate and red rock	99	1,010		
Dry sand	6	1,016		
Sand	6	1,022		

[1] Udden, J. A., and Phillips, D. McN., Geology of the oil and gas fields of Texas: Univ. Texas Bull. 246, 1912.

[2] *Idem*, pp. 217–219.

Log of Halsell well No. 1, etc.—Continued.

Driller's log.			Description of samples of rock.	
	Thickness.	Depth.	Depth at which sample was taken.	Geologist's notes.
	Feet.	*Feet.*	*Feet.*	
Putty	20	1,042		
Red rock	50	1,092		
Red mud	8	1,100		
Water, sand	50	1,150		
Blue mud	25	1,175		
Red and white sand	65	1,240		
Light-blue shale	15	1,255		
Black shale	20	1,275		
Red shale	30	1,305		
Brown shale	8	1,313		
Red rock	10	1,323		
Gray hard sand	2	1,325		
Red and blue mud	30	1,355		
Joint clay	10	1,365		
Light-blue shale	10	1,375		
White sand	35	1,410		
White slate	10	1,420		
Gray lime	16	1,436		
White sand	9	1,445		
Gray lime	10	1,455	1,450	Limestone and sand. The limestone contains much organic material, in which were noted Rhombopora, crinoid joints, spines of Productus, a minute apex of a gastropod, an ostracod, and *Fusulina cylindrica*.
Dark-blue slate	45	1,500		
Red and blue mud	3	1,503		
Rotten sand	5	1,508		
Sky-blue shale	5	1,513		
Red cave	22	1,535		
Dark-blue shale	15	1,550		
White sand	30	1,580		
Dark-blue shale	64	1,644		
Gray lime, hard	11	1,655	1,645	Limestone, sand, and a little shale; Chætetes noted.
Blue shale	44	1,800		
White sand	20	1,820		
Shale, breaks, caves	2	1,822	1,822	Limestone, shale, and sand. The shale is calcareous and emits sulphur in a closed tube before ignition.
Lime shells	10	1,832		
Gray sand, dry	5	1,837		
Blue shale	10	1,847		
Blue mud, caves	10	1,857		
Light-blue shale	38	1,895		
Dry sand	10	1,905		
Black slate	28	1,933		
Sand, salt water	20	1,953		
Blue marl	30	1,983	1,953	Gray calcareous shale, containing abundant Fusulina, pieces of crinoid spines, and an apex of a tall-spired gastropod.
Gray lime	25	2,008		
Blue marl	50	2,058		
Black slate, gritty	67	2,125	2,120-2,125	Dark bluish-gray shale with white porous chert containing silicified fragments of fossils. A part is sand with grains from 1 millimeter to 0.125 millimeter in diameter and showing crystalline facets, due to secondary growth. On the label of the samples was the note, "First top shell big salt sand."
			2,125	Yellowish-gray sand of fine texture. With this was some dark-gray shale, some crinoid fragments, and some fragments of white chert.
Sand, artesian flow of salt water.	45	2,170	2,130	Fine-textured yellow sand, with grains from 0.25 to 0.062 millimeter in diameter. Some gray shale containing calcareous material.
			2,135	Yellowish sand, gray, of fine texture.
			2,140	Dirty yellowish sand of fine texture.
			2,145	Dull grayish-yellow sand of fine texture.
			2,150	Mostly yellow sand. Some dark gray, or almost black shale, and some organic calcareous fragments. Many fragments of white chert and some of coal. The maximum ingredient of the sand is grains from 0.125 to 0.062 millimeter in diameter.
			2,155	Limestone, yellowish, organic, containing white and yellow chert, having a flat and rectangular cleavage. Rhombopora and crinoid stems were noted. One-fourth of the sample is bluish-gray shale. In this was noted a fragment of pyritized woody tissue.

Log of Halsell well No. 1, etc.—Continued.

Driller's log.	Thickness.	Depth.	Depth at which sample was taken.	Geologist's notes.
	Feet.	*Feet.*	*Feet.*	
Sand, artesian flow of salt water—contd.	45	2,170	2,160	Gray shale with some yellowish calcareous organic fragments and some white chert. Fusulina, crinoid stems (one was half an inch in diameter), the apex of a Murchisonia (?) and some thick spines noted.
			2,165	Yellowish crinoidal limestone, with some chert. There was also some dark gray shale. Fusulina present.
Break	5	2,175	2,175	Gray shale, calcareous, and containing some small flakes of mica.
Sand	5	2,180	2,180	Shale and limestone. The shale is almost black, and breaks into very thin fragments. One fragment bore the impression of a closely ribbed flat shell, half an inch to an inch in diameter, probably Aviculopecten. One-half of the sample is gray limestone, largely made up of organic fragments. The following fossils were noted: Fusulina (8 fragments), crinoid stems (20), Polypora (?) (2), Rhombopora (1), Retzia (?), very small (4), Chonetes (1), and a porcelaneous, single-apertured faraminifer(?).
Sand	5	2,185	....	
Do	5	2,190	2,185	Most of the sample is fine yellow sand. The rest is gray shale and organic yellow sand. In this were noted crinoid stems, fragments of shells, and spines of brachiopods.
			2,185	Dark-gray shale, with some thin layers of fine white sand.
Do	10	2,200	2,190	Gray crinoidal limestone with brachiopod spines, finely tuberculated crinoid fragments, and small pieces of shells.
			2,195	Dark-gray shale and yellowish limestone. Fossils noted: Fusulina, crinoid stems, spines of Productus, fragments of brachiopod shells, and some minute tests with a porcelaneous luster, from 0.5 to 1 millimeter long, oval, either a foramifer or an ostracod, and fragments of some large shell having a transverse columnar structure.
Hard brown shells	15	2,215	2,200	Dark-gray shale, minutely micaceous, containing thin and irregular layers of light gray sand of fine texture. Embedded fragments of leaves were noted.
			2,200	Gray shale containing calcareous fragments, and some shale containing carbonaceous fragments of vegetable origin. Fossils noted: Ostracod, apex of gastropod, bryozoa, crinoid stems, Chaetetes (?), brachiopod spines, a flat coiled small gastropod, a young Pleurotomaria, base of an echinoid spine.
Blue shale	10	2,225	2,215	Light-gray and soft sandstone with grains mostly from 0.25 to 0.062 millimeters in diameter, very slightly micaceous. There are also thin laminæ of coal showing parallel leaf-veins on the flat side.
Sand, dark clay	55	2,280	....	
Sand, dark gray, broken.	20	2,300	....	
Sand, light gray	15	2,335	....	
Brown shale	15	2,335	....	
Hard shells	15	2,350	....	
Light blue slate	5	2,355	2,350	Greenish-gray, slightly micaceous shale, with abundant fragments of Chaetetes (?), spines of Productus, crinoid stems, and other fossils of unknown kinds.
Brown shale	70	2,425	....	
Blue slate	25	2,450	....	
Brown limestone	50	2,500	....	
Blue shale	100	2,600	....	
Do	75	2,675	....	
Shells of hard sand with streaks of gray limestone.	25	2,700	....	
Blue shale	5	2,705	....	
Lime shells and streaks of blue shale.	5	2,710	....	
Lime and streaks of hard sand.	30	2,740	....	
Light-blue shale	228	2,968	2,958	

Log of Halsell well No. 1, etc.—Continued.

Driller's log.			Description of samples of rock.	
	Thickness.	Depth.	Depth at which sample was taken.	Geologist's notes.
	Feet.	*Feet.*	*Feet.*	
Sand, 6 feet, a break of 3 feet, and solid sand, 3 feet.	12	2,980	2,974	About one-half of this sample is a gray calcareous shale, containing here and there minute black shreds of vegetation. Most of the rest of the sample is a mixture of calcareous fragments and gray siliceous sand. Fossils noted: A few crinoid joints, pyritized woody fiber, and a piece of brachiopod valve.
			2,974–2,976	Dark, almost black shale, calcareous in spots and in part minutely micaceous. Some fine sand. The shale disintegrates when washed. Fossils noted: Crinoid stems and spines. On the label was written the word "brake."
Very black shale	240	3,220	3,015	Dark bluish-gray shale of fine texture, slightly calcareous, with occasional black, indistinct shreds of vegetation and minute flakes of mica. Fossil fragments exceedingly scarce.
Limestone shells	130	3,350	3,330	Black shale showing indistinct impressions of shreds of vegetation on fractured surfaces. Small embedded flakes of coaly material. Some shale shows alternate laminæ of fine gray sand. All this shale is fissile and sparingly micaceous. One-half or more of the sample is yellowish sand, with grains from 0.5 to 0.062 millimeter in diameter. There are also some limestone fragments.
Dark shale	32	3,382	....	
Light-gray sand (shows little water).	12	3,394	3,382–3,394	Dove-colored, slightly micaceous sandy shale and fine-grained sandstone, in about equal quantities.
Dark slate	21	3,415	....	
Sand	25	3,440	3,418–3,440	The greater part of the sample is black shale, slightly micaceous, splitting into long and slender shoepeg-like flakes, calcareous. Heated in a closed tube this shale decrepitates, gives off strong sulphurous fumes, and becomes magnetic. The sample included some sand and calcareous material. Two fragments of coal were noted. On the label is the note: "No water."
	....	....	3,430	Yellowish-white sand of mechanical composition about as follows: 0.5 to 0.25 millimeter, 5 per cent; 0.25 to 0.125 millimeter, 80 per cent; 40.125 to 0.062 millimeter, 15 per cent. With the sand are some large fragments of dark calcareous shale of fine texture. On the label was the note: "Middle of sand."
Dark-blue shale	255	3,695	....	
Dark shale	285	3,970	3,850	Dark-gray shale, with very thin layers of calcareous material. Minute flakes of mica noted, and also some crinoid stems. The shale emits sulphurous odor when heated in a closed tube.
	....	....	3,901–3,904	Dark-gray, almost black shale, of fine texture, very stiff and hard. When rubbed and washed in water, it hardly disintegrates at all, notably less than all the shale above this depth. A part of the sample is calcareous sandstone, light gray, containing a number of green grains (glauconite?). Heated in a closed tube it gives off sulphur fumes and becomes magnetic. Yellow chitinous flakes were noted in the shale. Fossils noted: Crinoid stems, cylindric straight spines, fragments showing rectangular cancellations, apparently of organic origin (seen under a $\frac{1}{4}$-inch objective), and an undoubted organic structure consisting of fragments of perforate shells of some foraminifer-like Endothyra. On the label was the word "top."
	....	....	3,904–3,906	Shale and organic fragmental limestone as in the preceding sample. Also some black shale and coal among all sizes of fragments. Crinoid stems noted.
	....	....	3,906–3,911	Black, indurated shale like the preceding two samples. When heated in a closed tube it emits bituminous fumes and oil. Fossils noted: Crinoid joints and fragments of shells.
Dark-gray lime; lost tool.	15	3,985	....	

For the purpose of comparing the position of the oil-producing sands and other unexposed beds in the Petrolia, Electra, and Burkburnett oil fields of northern Texas with the strata encountered in deep wells drilled in the Grandfield district, a few typical logs of wells in these oil fields and vicinity are plotted to scale on Plate III (in pocket). The writer has not attempted to correlate the beds in these sections, but has accepted the correlations given by Udden and Phillips[1] as being much more thorough than he could possibly make, especially as he has not had the advantage of field work in that area.

These authors say:

The limestone at 1,445 feet below the surface in the Halsell well is found to contain this fossil [*Fusulina cylindrica*], and no rock higher up in this well seems to be of a kind in which this fossil is at all likely to occur, excepting the other thin limestone reported at the depth from 1,420 to 1,436 feet. This part of the Halsell well section is doubtless also the equivalent of the deeper productive oil and gas sands in the two fields under investigation. These consist of shales, limestones, and sandstones, which lie at from 1,500 to 1,700 feet below the surface in the wells near Petrolia and at from 1,800 to 2,000 feet below the surface in the Electra field. This general correlation seems to be warranted by paleontologic evidence as well as by evidence based on the lithologic character of the beds explored by drilling.

The discussion of many well logs and a large amount of other extremely interesting data are given by these authors in the above cited report, and the correlations of these beds are summed up as follows:[2]

To sum up the essential correlations for these fuel fields [referring to Electra and Petrolia oil and gas fields]: The Bend formation is perhaps present near 3,900 feet below the surface in the southeast part or the areas studied. From about 3,900 to 1,800 feet below the surface the bedrock is an equivalent of the lower half of the Cisco, the Canyon, and probably the Strawn divisions on the Colorado River. The Bull Creek coal and its associated dark shales and other beds are probably the stratigraphic equivalents of the dark shales and productive sands lying at from 1,500 to 1,800 feet below the surface in the wells near Petrolia and at from 1,700 to 1,900 feet below the surface in the Electra wells. Some thin coal seams noted in the lower part of the Albany sediments in the Colorado River basin may be the stratigraphic equivalents of the zone producing some oil at about 750 feet below the surface in a part of the field at Petrolia and of the productive sands at about 1,000 feet below the surface near Electra.

We have shown that it is more than likely that the gas-bearing sands which lie from 550 to 700 feet below sea level in the Henrietta field are at the same horizon in the general section as the oil-bearing beds in the Electra fields, which lie some 200 or 300 feet deeper 40 miles farther west. We have presented three groups of facts which bear out this conclusion. The Beaverburk limestone shows that the Wichita beds lie practically horizontal on an east and west line for about 15 miles. Combining 90 observations made on dips in the area between Electra and Petrolia, we have found that if these dips be taken to represent the general structure of the terranes between these two points, the beds lie nearly horizontal. Comparing the strata explored in the two fuel fields we have also found that there is in the formations themselves a resemblance which

[1] Op. cit., p. 83.

[2] Op. cit., pp. 90–92.

confirms our belief that the deep productive sands in the two fields, as well as the upper sands, are to be correlated with each other.

Fortunately, however, we are not limited to evidence which makes our conclusions on this point almost certain, but still questionable. There is other evidence which, in connection with that already mentioned, must be fairly conclusive, even if the basis of facts involved is somewhat slender. This consists in the presence in the deeper oil-bearing deposits in both fields of a few identical fossils. The finding of these fossils also enables us to roughly correlate the underground section in this region with the general section of the Pennsylvanian in Texas.

The principal object of Plate III is to show the depths reached by wells in the Grandfield district and those at which oil and gas has been found in the fields of northern Texas and to show the apparent variations in depths below sea level of these sands where productive. From this plate it is evident that only one of the four wells drilled in the Grandfield district reached a depth sufficient to test the deeper and more widely productive sands. No definite correlations of surface beds have been made between the oil fields at Petrolia, Burkburnett, and Electra and the wells of the Grandfield district, but such work as has been done suggests that the rocks at the surface in the Electra and Burkburnett fields are not very far in vertical distance from those at the surface at both the George Cabella, the Big Pasture, and the Grandfield wells.

This plate shows all the information now available regarding the correlation of the unexposed rocks of the Grandfield district with the oil sands of the surrounding region.

ROCKS EXPOSED IN THE DISTRICT.

AGE AND GENERAL CHARACTER.

In most of the Grandfield district the hard rocks are hidden beneath a surficial mantle of loose, unconsolidated material consisting of (1) dune sand, spread over a broad belt adjacent to Red River; (2) a dark or reddish sandy to clay soil, largely wind-blown, covering most of the smooth slopes of the interstream areas; and (3) a red clay-silt alluvium found in the broad, flat valleys of Deep Red Run and its tributaries. Beneath this thin veneer of Quaternary beds, exposed in many places in breaks and along the valley sides, lies a thin bed of coarse, hard quartz-lime conglomerate (here named the Grandfield conglomerate), very persistent and rarely exceeding 5 feet in thickness, which has been variously classified as of Quaternary or of late Tertiary age.[1] It is underlain unconformably by "Red Beds" of Permian age which are correlated with the Wichita formation of northern Texas.

[1] Udden, J. A., and Phillips, D. McN., Geology of the oil and gas fields of Texas: Univ. Texas Bull. 246, p. 107, 1912.

CARBONIFEROUS SYSTEM (PERMIAN SERIES).

THICKNESS AND SUBDIVISIONS.

In the Grandfield district the lowest outcropping rocks are "Red Beds" of Permian age, but the total thickness of these beds can not be determined accurately from the data now available. In northern Texas, where more carefully studied by geologists, the "Red Beds" have been divided into three formations, the Wichita at the base and the Clear Fork and Double Mountain formations above. Gordon[1] estimates the thickness of the Wichita formation in Shackleford County, Tex., at 1,000 to 1,200 feet. Cummins[2] says: "These beds [the Wichita formation] are heaviest along the Big Wichita River, where they attain a thickness of 2,000 feet." He also assigns a thickness of 1,900 feet for the Clear Fork and 2,000 feet for the Double Mountain, thus giving the Permian series a maximum total thickness in northern Texas of about 5,900 feet.

It seems probable that the Clear Fork and Double Mountain formations are not present in the Grandfield district, the Permian series being represented by the lower portion of the Wichita formation. In the absence of an abundance of fossils there is no sure means of determining in well sections where the Permian leaves off and the Pennsylvanian begins. Udden[3] says:

> We know that the upper 300 feet or more at Electra belong to the Wichita formation, and that the shales and sands penetrated from 1,400 to 2,000 feet under the surface belong to the Cisco, but how much of the intervening 1,200 feet should be allotted to each we can only guess from the lithologic appearance of the section as made known by the driller's records.

This conclusion agrees with the writer's observations.

WICHITA FORMATION.

CHARACTER AND OCCURRENCE.

In Shackleford County, Tex., the Wichita formation consists of blue clays, blue, gray, and black shales, and thick beds of blue, gray, and yellowish limestones. Northward from that county the thickness of the limestone decreases abruptly and the thickness of the sandstone and shale correspondingly increases. In Archer and Baylor counties the formation contains prominent beds of red, white, and yellowish sandstone. The limestone diminishes in amount northward and practically disappears from the formation south of Red River, and in the same direction there is a rapid increase in the amount of red material,

---

[1] Gordon, C. H., Geology and underground waters of the Wichita region, north-central Texas: U. S. Geol. Survey Water-Supply Paper 317, 1913.

[2] Cummins, W. F., Texas Geol. Survey Second Ann. Rept., p. 401, 1890.

[3] Udden, J. A., and Phillips, D. McN., Geology of the oil and gas fields of Texas: Univ. Texas Bull. 246, p. 86.

consisting largely of red clay and soft sandstone. The upper portion of the Pennsylvanian series apparently shows the same change from blue to red sediments northward toward Red River from Young County, Tex., and where the contact between these two series is not exposed at the surface in Wichita and Clay counties it becomes more and more difficult to trace it northward by well records to the Grandfield district.

As already noted, the lowest rocks exposed in the Grandfield district belong to the Wichita formation. They outcrop along the bluffs of Red River in T. 5, Rs. 11 and 12 W., and consist of gray and red sandstone, red and gray shale, red, gray, and purplish clay, and thin layers of reddish to gray clay-limestone conglomerate. The greatest single outcrop of rocks in this district is in the S. ½ sec. 30, T. 5 S., R. 12 W., where the following section was measured:

Beds exposed in "breaks" on north side of Red River in sec. 30, T. 5 S., R. 12 W.

	Feet.
Quaternary:	
1. Sand, loose brownish to reddish, coarse, massive; seems to be wind blown; capping bluff	15–30
Permian (Wichita formation):	
2. Sandstone, reddish, thin bedded, ripple marked; poorly exposed under the loose sand	4
3. Clay or shale, whitish, with some thin-bedded shaly sandstone	2
4. Clay, red to grayish (mostly red), with some soft, reddish, thin, smooth, gray calcitic lime concretions; the slumping clay almost conceals a few thin beds of very soft clayey sandstone near the base	40
5. Sandstone and clay. Sandstone reddish, blocky to platy, cross-bedded and very irregular bedded. Changes to red clayey sandstone with light-colored streaks, thence to red clay carrying many roundish clay-lime concretions having a very rough surface and a burnt brick-red color. The beds change from sandstone to clay and back to sandstone within short horizontal distances	15
6. Clay and sandstone; deep-red clay, interbedded with and changing locally to reddish and grayish clayey sandstone. The clay in many places contains smooth roundish gray clay-limestone concretions	10
7. Sandstone: top part soft, locally massive, yellowish to greenish in places, contains near middle large round to flattish black concretions single and twinned, some of which are more than a foot in diameter; bottom part thin and irregular bedded, weathers reddish with canary-yellow streaks. These sandstones and concretions change horizontally into red clay and shale and are extremely variable in occurrence	11

Permian (Wichita formation)—Continued.	Feet.
8. Sandstone, dark gray and yellowish at base with black specks; changing to dark and harder limy irregularly bedded sandstone in middle, which carries flattish irregularly bedded layers of a very hard, close-grained, reddish to dark rock, which seems to be composed of rather coarse subangular grains of quartz cemented with limestone. These lenses resist erosion better than the adjacent beds and remain on the surface as irregular slabs after the other portions have been disintegrated	9
9. Sandstone, grayish to light canary-yellow, rather massive	7
10. Sandstone, massive, soft canary-yellow to dark leaden gray, containing remains of fossil plants and small amounts of copper ore in lower 5 feet	12
11. Clay and shale, whitish to light gray, changing to deep purple blocky clay with lumps and streaks of copper ore and shale or clay pebbles	2
12. Shale, clayey, red and gray to green	10
13. Conglomerate, clay-limestone; soft, gray to reddish, contains in places fragments of bones. This bed is in many places absent	2
14. Clay, deep red to purplish with one or more thin layers of soft impure whitish sandstone near base; clay contains in lower part considerable number of rather small gray, roundish calcitic clay-limestone concretions	8
15. Sandstone, 2-foot layer at top of soft whitish to gray sandstone which has the appearance of having become bleached and which in weathering forms cylindrical holes in upper surface (one-fourth to one-half inch in diameter) which trend in all directions in top layer. These holes appear to have been made by burrowing animals or worms in the ancient sand beach. Under this layer is a massive reddish irregular-bedded impure sandstone having many thin dark streaks made up of small round black specks which are slightly more resistant to weathering and appear as ridges on face of cliff. Near base is a massive layer carrying many round black cannonball-like concretions, the largest a foot in diameter. Sandstone very irregular bedded with many cross-bedded zones and whitish layer at base	21
16. Clay, deep red, with thin purplish and ashen-colored layers, a few very thin layers of soft gray sandstone, and a layer of clay pebbles in gray calcareous clay at the bottom	20
17. Sandstone, reddish, at top, changing to grayish toward bottom, massive irregular bedded	10

Permian (Wichita formation)—Continued.	Feet.
18. Clay, principally deep red, with thin layers of sandstone and sandy shale, beds very poorly exposed with about 10 feet of greenish clay or shale at river level; about	50
	233

This section was measured hurriedly, the writer expecting to return later and study in great detail the changes which each bed undergoes within this outcrop of more than a mile, but he was unable to do so. If several sections were made at different places along this outcrop, they would probably show considerable variation, especially above bed 11. In fact, at some places the sandstone above that bed is much thinner and in others is probably replaced entirely by red clay and shale. Sandstone 15 above is the most persistent stratum in the section, and the white bed at its top can be picked out with considerable certainty. A collection of poorly preserved fossil plants obtained from the lower 5 feet of sandstone 10 shows that the beds are of Permian age. Other sections of the formation along Red River are given below:

Section in bluff on north side of Red River in NW. ¼ sec. 5, T. 5 S., R. 11 W.

Quaternary:	Feet.
1. Sand, river, loose, massive, yellowish, unstratified, wind blown, at top of bluff	18
Permian (Wichita formation):	
2. Clay, red	4
3. Clay, red, with a few thin layers of light-colored sandstone	4
4. Sandstone, reddish, thin, fairly smooth bedded	5
5. Sandstone, reddish, thin bedded, platy to massive, with black hard limy plates and lenses which contain olive-green and canary-yellow clay pebbles	6
6. Concealed	1
7. Sandstone, yellowish to grayish, changing to whitish in places, weathers in peculiar tiny spirelike columns	3
8. Clay, whitish sandy clay with canary-yellow streaks	1
9. Concealed (probably ashen clay)	7
10. Clay, dark red	2
11. Clay, red	1
12. Sandstone, white, clayey	1
13. Clay, dark red, with thin white sandstone lens in middle	6
14. Sandstone, white, shaly	1
15. Clay, blocky, bright red	2
16. Clay, reddish at bottom, changing to ashen above, with white sandy blotches	6
17. Sand and alluvium of present flood plain down to water of river	8

About a mile farther east the following incomplete section was measured:

Incomplete composite section of rocks exposed in bluff on north side of Red River near middle of north line of sec. 4, T. 5 S., R. 11 W.

	Feet.
Quaternary:	
1. Sand, soft, loose, yellowish, capping bluff	4-20
2. Gravel, quartz, quartzite, and yellow clay pebbles, fragments of chert limestone, etc., unconsolidated	1-2
Permian (Wichita formation):	
3. Sandstone, gray to reddish, with dark limy harder layers	3
4. Clay, red to grayish, free from concretions, concealed at base	10
5. Concealed, about	10
6. Concealed on terrace by soft, unconsolidated wind-blown sand, unstratified and of Recent age	14
7. Clay, red, with thin whitish to reddish layers of sandstone, shaly at base	7
8. Sandstone, greenish or bluish to gray, sharp, fine grained, thin bedded, reddish platy layers at base	6
9. Sandstone, reddish, generally thin, cross-bedded and very irregular bedded, carrying dark hard limy concretions; at top a thin soft limy layer containing many small black specks	7
10. Conglomerate, clay-limestone, containing interstitial calcite, clay, and chert pebbles, many of which are yellow or brown; very irregular bedded and variable in occurrence	3
11. Sandstone, smooth bedded, reddish	1
12. Clay, red, containing thin plates of reddish sandstone	6
13. Sandstone, reddish, thin bedded, laminated, usually platy and cross-bedded, becoming coarse, massive, irregular bedded toward base; makes prominent cliff in bluff	10
14. Clay, red, to concealed beds	4
15. Concealed or poorly exposed to water of Red River; seems to be largely red clay with a few thin beds of red sandstone, about	55
	141-158

The above sections are typical of the larger exposures of the Wichita formation along Red River east of R. 13. West of that range the outcrops of Permian rocks along the north bank of Red River are very scarce and are uniformly of small vertical extent. The beds exposed are usually red clay and irregular beds of gray or reddish sandstone, which can not be correlated from one outcrop to another.

AUGER CONGLOMERATE LENTIL.

An exception to the rule just stated—that correlation of the Permian from outcrop to outcrop is impossible west of R. 13—was noted along the river bluff in the northwestern part of T. 5 S., R. 15 W., and northward for several miles on the "breaks" on the east side of Auger Creek. At these places occur imperfect exposures of a thin series of gray to reddish sandstone beds separated by red clay and containing a peculiar conglomerate consisting principally of limestone with small included balls of red and gray clay. These beds are so characteristic that they may be recognized with certainty at many places over the area back from Red River. The clay-limestone conglomerate and its associated beds of sandstone are here named the Auger conglomerate lentil, from the exposures on Auger Creek and also at "Old Fort Auger," the site of which is in the N. ½ sec. 6, T. 5 S., R. 15 W. The following is a fairly typical section of this series of beds:

Section of Auger conglomerate lentil and associated rocks exposed in "break" near head of small run in NW. ¼ sec. 6, T. 4 S., R. 15 W.

	Feet.
Quaternary:	
1. Soil concealing rocks at top of break	15–20
Permian (Wichita formation):	
Auger conglomerate lentil:	
2. Clay and sandstone; thin beds of whitish to reddish clayey sandstone in red clay, sandstone being very irregular bedded, reddish layers very thin and platy but false bedded	5
3. Sandstone, bluish white, clayey, some layers ripple marked, weathering in curly irregular layers. Other beds are characteristically cross-bedded at angles up to 20° from horizontal; grades below into rather massive sandstone layers that are reddish in places. At other places has thin bed of red clay near the middle; lower beds very irregular bedded	5
4. Conglomerate, clay-limestone, containing small clay pebbles interbedded with sharp gray to reddish sandstone in which occur many tiny black specks. The conglomerate appears in two layers in places, one near top and another near bottom. It is very irregular in bedding and thickness. Upper beds generally very hard and reddish, lowest bed often bluish gray. The matrix of the conglomerate is principally limestone and fine clay, cementing together small red and greenish to gray balls of clay	5–8
5. In places the lower conglomerate is cut out by a soft bluish-white sandstone; maximum thickness	2

	Feet.
Permian (Wichita formation)—Continued.	
Auger conglomerate lentil—Continued.	
6. Clay, bright red, jointed, containing roundish gray to reddish limestone concretions. Base of clay concealed below the bottom of the river	15
	45–55

These beds change greatly in thickness and appearance within the length of this outcrop and from one exposure to another. The conglomerate layers are everywhere very variable and are in places entirely absent. The sandstones are also very changeable in character and appearance, but the series taken as a whole, where well exposed, can be identified with reasonable certainty. Fortunately for the determination of the structure in this district the Auger conglomerate lentil outcrops at many places on streams tributary to Red River from the north and on Deep Red Run and its tributaries from the south, from Rs. 11 to 16 W. A typical outcrop of this conglomerate in the vicinity of Deep Red Run is given below:

Section of Auger conglomerate lentil and associated beds exposed on south side of valley of Deep Red Run in E. ½ NE. ¼ sec. 27, T. 3 S., R. 14 W., about 3½ miles northeast of Grandfield, Okla.

	Feet.
Quaternary:	
1. Soil, reddish, sandy, concealing rock at top of break	12
Permian (Wichita formation):	
Auger conglomerate lentil:	
2. Sandstone, reddish to grayish, very soft	3
3. Conglomerate, clay-limestone, light gray to reddish, very hard in places and very irregularly bedded and changeable in thickness, embedded in sandstone; maximum thickness	3
4. Sandstone and clay-limestone conglomerate. The sandstone is soft, sharp, massive, very irregular bedded, reddish to gray, the gray layers near top and bottom carrying numerous little black specks, presumably of some manganese mineral, which range in size from that of a pinhead to a quarter of an inch in diameter. These give the bed a peculiar speckled appearance. This sandstone also carries numerous small disklike sandstone concretions, from 1 to 2 inches in diameter. The clay-limestone conglomerate is interbedded with sandstone near the middle and ranges in thickness from 6 inches to 2 feet. It is reddish, hard, principally limestone, with some calcite, and includes many small lumps and balls of reddish to grayish clay	8
5. Conglomerate, clay-limestone; grayish limestone, carrying bluish and whitish clay lumps and balls. Very irregular in occurrence; frequently appears to be cut out by the overlying sandstone; maximum thickness	2

Permian (Wichita formation)—Continued.	Feet.
Auger conglomerate lentil—Continued.	
6. Clay, bright red, tough, containing considerable numbers of roundish grayish limestone concretions at top and larger reddish rough roundish ones near the bottom; also a 2-inch layer of clayey limestone near base and another 7 feet above base	22
7. Conglomerate, clay-limestone, soft, grayish, composed largely of small calcareous clay balls poorly cemented together by lime; less than	1
8. Clay, red, with a few calcareous concretions, down to alluvium of valley	4

No single exposure is typical of this conglomerate lentil, because each bed is variable from place to place. However, the lentil as a whole does not change so much from one outcrop to another that it may not be recognized wherever exposures are good. Toward the east, in Rs. 12 and 11, the clay-limestone conglomerate bed becomes more sandy and loses its characteristic lumpy conglomeratic appearance. If the writer's correlations are correct the conglomerate bed becomes darker and harder toward the east, and in many places has the smooth-grained appearance of a calcareous, somewhat ferruginous sandstone and weathers out of the inclosed sandstone as irregular, slablike lenses or more or less round to flattish concretionary masses, some of which are several feet in length.

The thin layers of sandstone in the red clay noted near the base of the above section appear to grow thicker toward the east, and in that direction other sandstones appear in the red clay at points in the stratigraphic section farther below the Auger lentil. The clay-limestone bed of the Auger lentil is generally present along the south side of Deep Red Run through R. 13, but in Rs. 12 and 11 the clay pebble content seems to be largely replaced by sand, making dark, hard, very limy sandstone concretions and slablike lenses in the gray "speckled" sandstone. The following section is generally typical of the Auger conglomerate in Rs. 11 and 12 W.

Section of Auger conglomerate lentil exposed in a small butte in SW. ¼ NE. ¼ sec. 13, T. 4 S., R. 12 W., about 4 miles northeast of Randlett.

	Feet.
1. Sandstone, whitish to dark, with many large dark platelike to roundish sand-limestone lenses from 1 to several feet in length. These lenses seem to be colored by a dark brittle substance, probably a manganese mineral	4
2. Sandstone, soft, whitish, rather massive to thin bedded, carrying a "speckled" layer (gray sandstone with small black specks) toward the top and a dark, mottled grayish to very dark sand-limestone bed at the base, which seems to contain considerable quantities of mineral resembling wad	4-6

	Feet.
3. Sandstone, soft, white (in places bluish white), thin-bedded to massive; very irregular in distribution and thickness; seems to be cut out in places by underlying red clay; greatest thickness	3
4. Clay, bright red, with very few grayish limestone concretions and some scattered gray spots a few inches in diameter	9
5. Sandstone, massive, lumpy, reddish, very clayey; disappears to sandy red clayey shale within 100 feet	7
6. Clay, red, tough; changes in places to clayey shale	10
7. Sandstone, milk-white to bluish white (very conspicuous), massive, blocky, very irregular in distribution, changes to a few inches of ripple-marked reddish clayey thin-bedded sandstone within 50 feet; greatest thickness	4
8. Clay, red, containing concretions of rough roundish limestone of peculiar burnt brick-red color. Other beds of this clay carry roundish concretions from 2 to 4 inches in diameter containing beautifully developed crystals of barite and also some peculiar brownish-yellow limestone concretions which fracture into halves. The thickness of these beds of clay could not be determined but is probably about	15
9. Sandstone, reddish, massive to thin bedded, very irregular-bedded and poorly exposed. This sandstone, with interbedded red clay, extends down to bed of Deep Red Run	20
	69–78

In this exposure sandstones 1 and 2 are very probably beds of the Auger lentil, which in the previous section included the lower layer of the clay-limestone conglomerate, but they may represent the upper layer of the Auger conglomerate, which in some places occurs a few feet above the speckled sandstone layer. Sandstone 3 is probably the irregular bluish-white layer that normally underlies the upper conglomerate layer of the Auger lentil.

The beds at the base of the above section are better exposed about 2 miles west of the section, where the rocks outcrop along the edges of a large " break " or " wash " covering several hundred acres.

Composite section of rocks exposed in a " break " in N. ½ sec. 15, T. 4 S., R. 12 W.

	Feet.
Quaternary:	
1. Concealed by soil (maximum thickness)	10
Permian (Wichita formation):	
2. Limestone, very sandy, with some red clay. In places a very limy sandstone and in others forms large roundish concretions as much as 4 feet in diameter. Usually the impure limestone is dark to reddish, close, very hard and brittle and occurs as flattish slablike lenses in soft grayish to reddish irregular-bedded sandstone. Usually found as slabs, bowlders, and concretionary masses cap-	

Permian (Wichita formation)—Continued.	Feet.
ping the tops of the breaks and scattered irregularly over the surface above the "breaks;" greatest thickness	5
3. Sandstone ("speckled" bed), gray to slightly reddish, soft, sharp, with many small black specks. Sandstone has same sharp, brittle, homogeneous character wherever seen	2–4
4. Sandstone, soft, bluish, white, cross-bedded, and laminated, very irregular in occurrence; greatest thickness	2
5. Conglomerate; soft gray to red clay-limestone beds, the balls of clay being very small and as a rule not closely cemented; very irregular in occurrence and appears to be at places locally unconformable on the red clay below	1
6. Clay, bright red, with occasional small white splotches (same as the clay below the typical Auger conglomerate lentil)	4–10
7. Clay or sandstone, generally red but containing purplish and ashen zones; very tough; changes frequently to sandy clay or shale, which at many places is replaced by reddish to white or bluish, very soft, blocky, massive, very irregular-bedded sandstones. At places where these sandstone layers are thin or absent the clay contains many rough roundish, burnt brick-red clay-limestone concretions, the largest 6 or 8 inches in diameter, with very rough, sharp surfaces	8–20
8. Sandstone, reddish to gray, shaly, choppy, ripple-marked; poorly exposed; concealed at top and bottom	3
9. Concealed	2
10. Sandstone, dark, hard, thin bedded, limy	1
11. Concealed (probably of red color)	1
12. Sandstone, grayish, with dark to reddish-brown hard balls from one-fourth to three-eighths inch in diameter, composed of iron-manganese minerals and limestone. In places this bed is black, with gray splotches	2–4
13. Concealed (probably red clay)	3
14. Sandstone, whitish to gray; hard, thin bedded	1
15. Sandstone, reddish, cross-bedded; very thin platy layers which in places are extremely smooth, breaking out in sheets 2 by 3 feet by one-half inch in thickness; characteristic fine threadlike ridges of grayish limestone run at different angles across plates	1–2
16. Clay red	1–3
17. Sandstone, red, thin bedded to massive, very irregular bedded; lower bed cross-bedded	3
18. Clay, red, and thin, irregular-bedded, rather clayey sandstone	4

Permian (Wichita formation)—Continued.	Feet.
19. Sandstone; soft, reddish, choppy, ripple marked, with thin grayish bed at top	2-3
20. Sandstone, massive, deep red, irregular bedded, with dark, harder layers one-fourth inch thick, which are reddish on fresh fracture	8
21. Sandstone, reddish, hard, limy, interbedded with red clay and clayey thin-bedded sandstone	3
22. Sandstone, whitish, soft, irregular bedded; somewhat massive cross-bedded layer at top and changing to red sandstone below; very irregular in occurrence; exposure suggests an unconformity at bottom; greatest thickness	3
23. Sandstone, red, impure, massive, blocky, irregular bedded, extending down to bed of creek	3-5
	101

These sections have been selected to show the general character of the Permian rocks exposed in the Grandfield district. They will serve as guides in the more detailed discussion of other and generally poorer exposures of the Auger conglomerate, which are used to determine the general structure or dip of the Permian strata in this territory. (See description of the rocks by townships, pp. 34-74.)

TERTIARY OR QUATERNARY SYSTEM.

GRANDFIELD CONGLOMERATE.

In this district there was observed at many places a thin bed of peculiar reddish conglomerate, consisting of a matrix of red clay and limestone inclosing many pebbles of quartz, quartzite, and a few of granite, together with fragments of chert and occasional pieces of limestone and silicified wood. The pebbles are waterworn and in general fairly well rounded, and the largest are 3 inches or more in diameter. This conglomerate is a compact, indurated bed, surprisingly uniform in character and probably averaging 3 or 4 feet in thickness. It is widely exposed, outcropping at many places on the broad divide between Red River and Deep Red Run and along both sides of the valley of the latter stream across the district. It is here named the Grandfield conglomerate, from the town of Grandfield, where it is well exposed on the south rim of the hill on which the town is built. It lies just below the surface at many places in this town. It also caps a dome-shaped hill, known locally as Curtis Hill, in the N. ½ sec. 13, T. 4 S., R. 15 W., and is found along the noses of the hills adjacent to most of the large tributaries to Deep Red Run from the north in this district.

The Grandfield conglomerate everywhere lies unconformably upon the Wichita formation (Permian), and displays a structure that is surprisingly conformable to the present topography, being high on

the divides and low near the valleys. For want of time in the field little study was given to this conglomerate and the data obtained were noted incidentally in mapping the Permian rocks. By further work it will probably be correlated with some portion of the Seymour formation, in Wichita County, Tex., described by Gordon [1] and referred by him to the Pleistocene. It very closely resembles the conglomerate seen by Udden and Phillips [2] on some of the higher ridges near and north of the Electra oil fields, which they describe as follows:

> A conglomerate which has been variously classified as of Pleistocene or of late Tertiary age should perhaps be noted, for the reason that it has been mistaken by some for a part of the terranes whose structure determines the oil accumulations in these fields.
>
> This conglomerate is of so late an origin that its distribution is clearly to some extent related to the topography developed by the present drainage. It lies high up on the divides and low down in the larger valleys, and can therefore not have the remotest connection with the structures of the Paleozoic series. It was noted on some of the highest hills on the divide between the Wichita and the Red River east from Electra, and on some of the hills north and west of Iowa Park. It caps the bluffs on the north side of the Wichita at several points southwest of Iowa Park. It was noted on the north shelf of Beaver Creek, at a point nearly due south of Electra, and again it was found capping the highest point of land on the divide between this creek and the Wichita River, in the southwest corner of Wichita County. Everywhere this conglomerate resembles stream gravel except as to its indurated condition. It is cemented with copious calcareous material, often of a cinnamon color. Cross-bedded sand is generally interbedded with the gravel, and occasionally it contains streaks of yellow and calcareous silt. It appears that this conglomerate is one of the remnants of a long series of stream sediments which have been laid down on the Plains during a time dating back from the later Tertiary age to the late Pleistocene.

The writer did not attempt to trace the outcrops of this conglomerate in the Grandfield district. A casual study of exposures, however, suggested strongly that the Grandfield is not the only quartz conglomerate there present, but that at places along Deep Red Run and many of its larger tributaries there are local thin beds of quartz and quartzite pebbles which are distinctly younger than the Grandfield conglomerate and which were probably derived from that bed by weathering and were redeposited along the streams. These secondary quartz pebble beds are usually unindurated or very poorly cemented and, as a rule, appear to contain a larger percentage of pebbles. The writer was able to distinguish with considerable certainty between the Grandfield and these younger gravels, but made no attempt to gather data to fix exactly their relative ages.

The Grandfield is surprisingly uniform in composition, appearance, thickness, and hardness throughout the district, and its uniform

[1] Gordon, C. H., U. S. Geol. Survey Water-Supply Paper 317, p. 30, 1913.
[2] Udden, J. A., and Phillips, D. McN., Univ. Texas Bull. 246, p. 107, 1912.

character suggests that it may not be a stream deposit. Its structure does show a very marked relation to the topography, the bed being present along the higher divides and in the points of the low hills adjacent to the larger streams. Notwithstanding the unconformity between this conglomerate and the underlying Permian rocks the structure of the two formations is very much alike, as may be seen from the elevations shown in Plate IV (in pocket). This suggests that the Grandfield conglomerate may have been deposited on a fairly smooth, even surface and later subjected to slight deformation, and that subsequent streams working in the soft fine sand and clay beds above this hard resistant layer have carved the surface roughly conformable to it.

The unconformity at the base of this conglomerate is clearly marked. It seems to be least at the south, where in places as much as 50 feet of red clay intervenes between the Grandfield conglomerate and the Auger conglomerate lentil below, and greatest toward the north, where in places the Grandfield conglomerate cuts out entirely the Auger lentil and rests on red clay several feet below its horizon.

QUATERNARY SYSTEM.

Gravels.—Thin beds of loose gravel consisting largely of quartz, quartzite, and some chert were found at a number of places adjacent to the larger streams. As stated above, this gravel was probably derived from the disintegration of the Grandfield conglomerate and deposited at favorable places by the streams. Some of these beds of gravel seem to occupy poorly preserved terraces a few feet above the present valleys. A thin bed of fine quartz gravel, prevailingly amber colored, underlies the deep dune sand at the top of the bluffs at a few places on the north side of Red River in Rs. 11 to 15, inclusive, but a detailed study of this bed was not made.

At a number of places scattered quartz and quartzite, well-rounded to subangular pebbles, the largest 4 inches in diameter, were seen on the surface along the broad divide between Red River and Deep Red Run. The position of some of these pebbles seems to preclude the possibility that they were derived from the Grandfield conglomerate, and it seems probable that they are, in part at least, remnants of later deposits.

Alluvium.—Deep Red Run and all its larger tributaries flow in relatively broad, flat, alluvium-filled valleys. This alluvium is a fine to sandy red clay and silt, derived from the exposed rocks of the interstream areas. Red River, which, as already stated, has a very narrow flood plain and a broad bed, is closely bordered by dunes of wind-blown sand that rise as much as 100 feet above flood level. Throughout most of the year the bed of the river is dry, thin threads

of water meandering from side to side across flat bars of sand and mud. A typical view of the bed of this river is given in Plate II, *A*, page 8.

Dune sand and soil.—A belt of country, 1 to 2 miles wide, adjacent to Red River, extending across this district, is covered by hills of drifting sand, some of which reach a height of probably 75 feet above the general level. Permian beds lying inland from these sand dunes are covered by a thick bed of wind-blown sand, which forms a fairly even surface and through which the streams have trenched narrow ditchlike valleys. Farther back from Red River, toward the top of the divide between that stream and Deep Red Run, the mantle of wind-blown material grows thinner and finer until in places it has the general appearance of a coarse loess, and in other places the soil is dark or black and seems to contain a relatively small amount of wind-blown material.

STRUCTURE.

The structure of the rocks in the Grandfield district has not been determined in detail, and in some parts of the district it is too obscure to be mapped with any degree of certainty. This structure is shown on Plate IV by numbers indicating the elevation above sea level of the Auger conglomerate lentil and also by structure contours connecting points of equal elevation on this bed. These contours are drawn on the horizon of the Auger conglomerate, but owing to the variability of the beds that make up this conglomerate no definite layer could be used as a key horizon throughout the area, so the elevations of this lentil as shown on Plate IV may be locally as much as 10 feet in error.

DEVOL ANTICLINE.

The most important structural feature recognized in this brief reconnaissance of the district is an anticline that crosses it in a sinuous line trending generally east-southeast and west-northwest. Along the axis of this anticline lie a number of small elongated domes that are separated by low structural saddles. The rocks over the entire district generally dip eastward, and this dip is shown in the height of the Devol anticline. The axis of this fold in the Auger conglomerate dips from an elevation of about 1,160 feet at the western side of the district to about 1,040 feet at its eastern edge, a distance of about 24 miles. Within the district the highest portion of this anticline is in its western part, on one of two local domes, one near the center and the other in the extreme northwest corner of T. 4 S., R. 15 W., and the adjacent portions of T. 3 S., R. 15 W., and Tps. 3 and 4 S., R. 16 W. From near the center of T. 4 S., R. 15 W., the rocks dip in all directions but mostly to the north and south. There is

evidence that a secondary fold trends almost south from the center of this dome through secs. 21 and 22 and possibly into or through secs. 27, 28, 33, 34, and 35, and in this general direction to Red River, but no direct evidence of this fold was obtained farther south than secs. 27 and 28. From this dome another secondary fold appears to trend eastward to the vicinity of Curtis Hill in sec. 13, and from this point southeastward its axis passes through secs. 9, 28, 29, 30, 33, and possibly sec. 34, T. 4 S., R. 14 W. The axis of this fold is rather definitely located as far south as sec. 29, T. 4 S., R. 14 W., and there is some evidence of its presence still farther southeast, but its position could not be determined with certainty beyond the point indicated. From this dome eastward along the axis of the fold the rocks pitch slightly to the northeast corner of T. 4 S., R. 15 W. They rise again to the top of a small elongated dome in the vicinity of Grandfield.

A similar dome occurs in secs. 6, 7, 8, 9, and 16, T. 4 S., R. 13 W. This is separated from the dome at Grandfield by a flat saddle in the northern portion of sec. 2, T. 4 S., R. 14 W.

There appears to be a somewhat smaller dome in secs. 25, 26, and 27, T. 4 S., R. 13 W., but owing to lack of outcrops south of this location the outline of this dome could not be determined. From the center of this dome eastward the rocks appear to pitch gradually along the axis of the fold to some point near the center of sec. 26, T. 4 S., R. 12 W., from which they rise slightly to a small dome in secs. 24 and 25, T. 4 S., R. 12 W., and possibly in sec. 30, T. 4 S., R. 11 W., beyond which point the position of the axis of this fold could not be traced.

DEEP RED SYNCLINE.

Another important structural feature of this district is a broad, flat syncline or structural trough which lies north of and roughly parallel to the Devol anticline. The axis of this fold pitches slightly toward the east, but is somewhat modified by one or two shallow basins. The exact position of the axis of this syncline at many places could not be determined. The available data indicate that it passes a short distance south of Loveland in a northwest-southeast direction that is roughly coincident with the trend of the valley of Slough Fork of Deep Red Run. From the map (Pl. IV) it will be noted that there appears to be a small shallow basin in the bottom of this trough west and northwest of Loveland, in sec. 8, T. 3 S., R. 14 W. From this basin the axis of the trough seems to rise slightly to a point southwest of Loveland and thence to pitch eastward at a very low angle to some point near the northwest corner of sec. 21, T. 3 S., R. 14 W., which is the bottom of a small basin along this trough.

A similar larger and deeper basin along the axis of this trough is in sec. 13, T. 3 S., R. 14 W., and secs. 17 and 18, T. 3 S., R. 13 W. From the center of this basin there seems to be a slight rise in the trough to the southwest corner of sec. 16, T. 3 S., R. 13 W. From this point eastward the depth and position of this trough is uncertain, but the available evidence suggests that it becomes deeper and lower toward the east.

MINOR ANTICLINES.

The numbers and contours on Plate IV indicate the presence of several minor folds in the Grandfield district, the most important of which is a clearly marked anticline that is partially revealed by outcrops in the bluffs of Red River in the southwestern portion of T. 5 S., R. 12 W. These outcrops, in secs. 30, 31, and 32, show a very marked dip to the northwest, amounting probably to as much as 100 feet within less than 1½ miles. The accompanying view (Pl. V, *A*, taken from the bed of Red River opposite the bluffs in the NE. ¼ sec. 31, T. 5 S., R. 12 W., shows faintly the dip of the beds toward the west. To represent this dip the contour lines on Plate IV have been drawn in two directions. In one set the contours trend a little north of west and in the other set they have a general northeast-southwest direction. There is not enough geologic evidence available to show which of these two sets of contours is more nearly correct.

Udden [1] maps a very pronounced fold, with a northeast-southwest trend, in the Petrolia oil and gas field in the northern part of Clay County, Tex. His larger map,[2] which shows the general dip of the rocks of the region, gives some evidence that this fold continues toward the northwest and that it may cross Red River somewhere in the southern part of T. 5 S., R. 12 W., in the Grandfield district; so it seems barely possible that the relatively steep dip shown by these exposures in the southwestern part of this township may be on the west limb of this fold. If this is true, the fold may have a north-northwest trend through this township, the axis crossing the northwestern part of T. 5 S., R. 13 W., and joining the Devol anticline at the small dome in the southeastern part of T. 4 S., R. 13 W., but there is no direct geologic evidence to substantiate this suggestion. On the other hand, it seems probable that the Burkburnett oil fields, which lie between 4 and 5 miles west-southwest of these outcrops, may be on an anticline, and that, if this anticline trends east-northeast south-southwest, it may be the same as that shown by the outcrops in the southwestern part of T. 5 S., R. 12 W. If this is true, the axis of the Burkburnett fold may continue north-

[1] Udden, J. A., and Phillips, D. McN., Univ. Texas Bull. 246, Pl. II, 1912.
[2] Idem, Pl. I.

eastward and be shown by the exposures in secs. 9, 10, 15, and 16, and 1 and 2 of T. 5 S., R. 12 W. The evidence for each of these two structural conditions is about equal. It is impossible to determine the structural conditions in T. 5 S., R. 12 W., except that the southern portion of this township, especially secs. 28, 29, 32, and 33, are on or near the axis of a pronounced anticline, the trend of which is uncertain.

The rocks north of the Deep Red syncline appear to rise rather uniformly, but the exposures are too poor and too scarce to permit a close delineation of the structure. Attention should be called, however, to the relatively rapid rise in the beds from this syncline northward in the northeastern part of T. 3 S., R. 14 W. The trend of the contours in this area also suggests that a local dome or anticline may be situated a short distance north of sec. 2 in T. 2 S., R. 14 W. There is also some evidence of a low fold in portions of sec. 9, T. 3 S., R. 13 W.

LOCAL SYNCLINES.

South of the Devol anticline there appears to be a local syncline, the axis of which crosses T. 4 S., R. 14 W., in a northwest-southeast direction and seems to cross the valley of Big Blue Creek near its junction with Little Blue Creek and roughly to parallel the valley of the latter stream to the middle western part of sec. 7, T. 4 S., R. 14 W. The axis of this fold pitches to the southeast, but there is little or no evidence to show its trend southeast of the valley of Big Blue Creek.

A small secondary syncline appears to parallel the valley of Auger Creek in the southwestern portion of T. 4 S., R. 15 W., the pitch of the fold being somewhat steep toward the south. A similar fold is believed to lie somewhat west of the valley of Curtis Creek, in the southeastern portion of T. 4 S., R. 15 W., but owing to the poor exposures in both of these areas the exact position of these troughs can not be determined.

North of the Devol anticline the contour lines on Plate IV show many small local synclines branching off from the Deep Red syncline and dying out against the north limb of the Devol anticline, but none of these requires special description.

DETAILED STRATIGRAPHY AND STRUCTURE OF EXPOSED ROCKS, BY TOWNSHIPS.

T. 5 S., R. 16 W.

Red River cuts across the northern boundary of T. 5 S., R. 16 W., so that only a narrow strip of the northern tier of sections east of sec. 6 is on the north side of the river. This area is covered entirely by sand dunes, but Permian rocks outcrop in the bluff on the south side

A. NORTH BLUFF OF RED RIVER IN NE. ¼ SEC. 31, T. 5 S., R. 12 W.
Showing westward dip of Permian rocks.

B. SOUTH BLUFF OF RED RIVER IN T. 5 S., R. 16 W.
Showing westward dip of Permian sandstone.

C. EASTERN PART OF BLUFF SHOWN IN *B*.

(Texas side) of the river in the southern part of sec. 3. The accompanying views (Pl. V, *B*, *C*) and the following section show the general appearance and character of the best of these outcrops.

Section in bluff on south side of Red River in sec. 3, T. 5 S., R. 16 W.

	Feet.
1. Concealed by dune sand at top, probably	40
2. Sandstone (not shown in Pl. V, *C*) massive, reddish, capping bluff east of exposure shown in Pl. V, *C*. Appears to be resting on red clay, but base is poorly exposed	20–25
3. Clay, red (poorly exposed in Pl. V, *C*), which appears to contain a soft whitish sandstone or clay-limestone conglomerate toward top; probably	5–15
4. Sandstone, reddish, thin bedded, laminated with some whitish layers, and containing several lentils of reddish clay-limestone conglomerate which ranges in thickness from 1 foot to as much as 10 feet, within length of exposure. This sandstone seems to lie unconformably on the red clay below and to be very irregularly bedded throughout	10–25
5. Sandstone, whitish, clayey, lumpy, embedded in red clay (not shown in Pl. V, *C*); greatest thickness probably	4
6. Clay, bright red, at base above water level; greatest thickness	10
	75–119

East of the above section a grayish clay-limestone conglomerate bed outcrops along the river bluffs beneath dune sand. Below this conglomerate a white massive sandstone 4 feet thick is poorly exposed a few feet above the river. Higher bluffs farther back from the river contain other outcrops of thin beds of gray and reddish sandstone and reddish clay-limestone conglomerate which appear to rise toward the east. This rise is also suggested by the exposure shown in Plate V, *B*. These clay-limestone conglomerate beds resemble closely those of the Auger conglomerate lentil, though the associated sandstone beds are not typical. If this is the Auger conglomerate, it is one of the most westerly exposures observed. It probably ranges in elevation between 1,040 and 1,070 feet above sea level at this locality.

T. 4 S., R. 16 W.

Red River crosses the southwest corner of T. 4 S., R. 16 W., and Settler Creek, flowing from north to south through the central part of the township, drains most of it. The south half of the township is covered largely by dune sand and a deep sandy soil, which is mostly, if not all, wind blown. Permian rocks come to the surface at few places. One of these outcrops is in a small break on the east

bank of Settler Creek, almost in the center of the NW. ¼ sec. 27, where the following section is exposed:

Section in NW. ¼ sec. 27, T. 4 S., R. 16 W.

1. Top concealed by dune sand.	
	Feet.
2. Gravel at top of break, largely quartz, unindurated; looks like stream gravel of Recent age	1–3
3. Sandstone, reddish, massive, irregularly bedded at base changing to thin bedded and clayey at top	3
4. Sandstone, gray, with black specks; soft, with typical appearance of "speckled" bed of the Auger conglomerate lentil, about	1
5. Sandstone, soft, bluish white, clayey, looks like basal bed of Auger conglomerate	½–1
6. Clay, bright red	8
7. Sandstone, red, soft, clayey, badly weathered to bed of creek	4
	17½–20

Bed 4 of the above section seems to be at the horizon of the clay-limestone conglomerate of the Auger lentil, which is locally absent. If this correlation is correct, there seems to be not more than 15 feet dip in the beds from this place to the outcrops described above in south bluff of Red River 3 miles farther south. No other exposures of recognizable Permian beds were seen on Settler Creek in this township. An extensive break occurs in red clay on the east side of the valley along a part of the west edge of sec. 10, and some small exposures of red clay were seen in the SW. ¼ sec. 3 and the SE. ¼ sec. 4.

The dump from a shallow water well in the southwest corner of the SW. ¼ sec. 2 contained some bowlders of red sandstone in red clay which could not be correlated with any other Permian exposures. Near the head of a small tributary to Red River, in the NE. ¼ of sec. 23, a bed of quartz and quartzite pebbles is exposed on the east side of the run, and below this bed is a poor outcrop of reddish clay-limestone conglomerate which may belong to the Auger conglomerate lentil. No elevation of this outcrop was obtained. At the southeast corner of sec. 23 a bed of quartz and quartzite gravel outcrops beneath dune sand and at places this bed is cemented by lime into a thin bed of reddish quartz conglomerate that resembles the Grandfield conglomerate.

The low divide between Settler Creek and Auger Creek traverses the W. ½ sec. 13 and the E. ½ sec. 14 from northeast to southwest. Two or three low domes on this divide are capped by a bed of quartz and quartzite pebbles, which may have come from the disintegration of the Grandfield conglomerate in place.

No examination was made of a large part of the area in this township west of Settler Creek because it appeared to be destitute of good exposures of recognizable Permian beds.

T. 3 S., R. 16 W.

Only the southeastern part of T. 3 S., R. 16 W., was examined and this in the briefest manner. The lack of good exposures over the area covered showed the uselessness of attempting to map with accuracy the structure of the Permian rocks in it. The writer did not go north or west of lines running through the middle of sec. 16.

Red clay, seemingly of Permian age, is revealed by low "breaks" along tributaries to Deep Red Run in parts of secs. 13, 14, 15, 16, 21, 22, 27, and 28. At a few places at the top of these breaks is a thin bed of clayey sandstone, generally reddish in color, but showing many round gray spots, ranging from tiny specks to patches probably 2 inches in diameter. A precisely similar sandstone, which lies a few feet above the Auger conglomerate, was noted at many places farther east. For convenience of description this bed is referred to as the "spotted sandstone layer." The gray patches are thinnest across the bedding planes and many of them are very thin in comparison with their diameter. At a few places in these breaks a layer of soft grayish limy clay, from 6 inches to a foot or more in thickness, is exposed in bright-red clay a few feet below the "spotted sandstone layer." A few feet above this sandstone is a bed of quartz and quartzite pebbles, most of which are well rounded. This bed is poorly exposed and apparently unindurated, but there were in places small bowlders of reddish limy matrix, including a few quartz pebbles, looking very much like the Grandfield conglomerate, and it seems probable that this conglomerate lies a few feet below the surface over most of the southeast quarter of the township, as similar material is frequently seen at the mouths of the burrows of prairie dogs. A spotted layer of sandstone, very similar in appearance to that described above, was thrown out of a 5-foot hole dug for water near the middle of the east line of the NE. ¼ sec. 26. If this is the same layer as that seen in the south bank of a small run at the southern border of the SW. ¼ sec. 14 there is a slight northward dip between these exposures.

T. 3 S., R. 15 W.

T. 3 S., R. 15 W., is drained by Deep Red Run and its tributaries. The Wichita Falls & Northwestern Railway crosses it from northeast to southwest. The town of Loveland is situated near its center, in secs. 9 and 16. In the part of the township that lies northeast of Slough Fork of Deep Red Run the surface is very flat, and the

larger streams have wide alluvium-covered valleys and low bluffs. The soil is generally a fine stiff clay, dark brown to red. In this part of the township not more than 6 good exposures of sandstone and clay-limestone conglomerate were seen. One of these is a rather thick reddish bed of clay-limestone conglomerate and some light to reddish sandstone, encountered from 16 to 18 feet below the surface in a dug well on the south edge of the SE. ¼ sec. 5. This bed closely resembles, and probably belongs to, the Auger conglomerate. It stands about 1,062 feet above sea level. This conglomerate is thought to be at the same horizon as one that outcrops on the road south of Loveland, near the southeast corner of the town. The outcrop at that place stands about 1,066 feet above sea level.

On the south side of the valley of Middle Fork of Deep Red Run and on the east side of the NE. ¼ sec. 14 a typical outcrop of the "speckled sandstone layer" of the Auger conglomerate shows along the road and in the bluffs toward the west. Here the lower layer of the clay-limestone conglomerate of the Auger lentil is absent in places and is replaced by white clayey sandstone. This is unquestionably at the Auger horizon. Its elevation ranges from about 1,058 to 1,062 feet above sea level, the rise being a local one, toward the east. Near the center of the SE. ¼ sec. 13, at a small pond, is a rather poor outcrop of the "speckled sandstone layer" of the Auger lentil having a few feet above it a quartz-gravel-limestone conglomerate, probably the Grandfield. Other sandstones, exposed a short distance north of this outcrop in the southern part of the NE. ¼ sec. 13, help to identify definitely the "speckled sandstone layer" as the Auger lentil. It has an elevation here of about 1,036 feet. The outcrops along this line continue eastward through T. 3 S., R. 14 W., and are discussed under that township. On the south bank of the creek, near the eastern border of the SW. ¼ sec. 3, is a bed of coarse to fine partly indurated quartz gravel, which in places is as much as 10 feet thick. This gravel seems to be younger than the Grandfield and is probably a local stream deposit, the quartz and quartzite pebbles of which come from the disintegration of the Grandfield at near-by places. Similar gravel beds were noted along the sides of the valley of this stream in secs. 2, 3, and 4. A low, round hill capped by a quartz conglomerate closely resembling the Grandfield stands near the middle of the SW. ¼ sec. 1.

A deep well was completed in 1912 just north of Loveland, near the center of the NE. ¼ sec. 9. This well did not produce oil or gas in paying quantities and is said to have been abandoned. A partial section of this well is given in Plate III (in pocket).

South of Slough Fork of Deep Red Run and adjacent to the valley of that stream is a broad belt of badland country, in which occur a great many "breaks" or washes, developed in fine red clay of

Permian age. The character of the rocks exposed in these breaks and the distribution of the exposures renders the determination of the structure very difficult. The Auger conglomerate is typically exposed on the township line south of the northeast corner of sec. 25 and at another place in the SW. ¼ SE. ¼ sec. 17. At these places the "speckled sandstone layer" and other associated beds of the Auger conglomerate are present. This conglomerate is in two well-marked divisions. The lower layer is below, or interstratified with, the "speckled sandstone bed." The upper conglomerate layer is associated with thin beds of reddish impure sandstone and red clay and at places seems to be as much as 12 to probably 18 feet above the lower one. Each layer and its associated beds have local characteristics which render identification possible where good exposures occur, but it is impossible to trace the beds by continuous outcrop. A collection of fossil bones was obtained from the red clay immediately overlying what appears to be the upper layer of the Auger conglomerate where it is exposed in a large break in the east-central part of the NW. ¼ NW. ¼ sec. 28. These were identified by Mr. C. W. Gilmore, of the National Museum, as belonging to the Permian reptile Dimetrodon, but "the bones are too fragmentary to permit the determination of the species."

Over much of this part of the township the sandstones accompanying the lower conglomerate of the Auger lentil are not present, their horizons being occupied by red sandy clay with limestone nodules. The sandstones of the lower part of the Auger lentil are absent from the Permian outcrops along the creek in the northern halves of secs. 17 and 18, but here the upper part of the Auger lentil, consisting of clay-limestone conglomerate in red clay, is exposed in the breaks with a bed of thin reddish platy limy sandstone having the characteristic choppy ripple marks and round grayish spots of the sandstone in T. 3 S., R. 16 W., already described as the "spotted sandstone layer." The following section exposed in a great break in sec. 31 is typical of the Permian outcrops in this vicinity.

Section of rocks exposed in break in the NE. ¼ SE. ¼ sec. 31, T. 3 S., R. 15 W.

	Feet.
Tertiary or Quaternary (Grandfield conglomerate):	
1. Quartz and quartzite pebbles, the largest 4 inches in diameter, conglomerate badly disintegrated, with bed of residual pebbles in soil at top of hill	2–3
Permian (Wichita formation):	
2. Concealed on hill slope above break, probably	8
3. Sandstone, reddish, rather thin, platy (plates 4 feet square, less than one-half inch thick), caps top of break, very similar to sandstone accompanying clay limestone in secs. 17 and 18	[illegible]

Permian (Wichita formation)—Continued.	Feet.
4. Conglomerate, clay-limestone, soft, whitish, variable; this is probably upper bed of Auger conglomerate lentil, greatest thickness	2
5. Clay, dark, dull red	3
6. Sandstone and clay, red; thin-bedded sandstone interbedded with red clay	5
7. Sandstone, whitish, false bedded, soft, lumpy, very irregular in occurrence, greatest thickness	2
8. Clay, bright red, with many roundish grayish limestone nodules; typical under clay of the Auger conglomerate lentil	10
9. Clay, whitish, limy, almost clay-limestone, conglomerate in places	1
10. Clay, bright red, with typical roundish, rough-surfaced burnt red limestone-clay concretions, down to base of breaks	5

The above section is by no means typical of the Auger conglomerate farther east, in the vicinity of Grandfield, but there seems to be enough stratigraphic evidence to justify the conclusion that the sandstone beds thin greatly toward the west across the district and that this section accords with this general decrease in thickness of these beds.

Spirit-level lines were run to many exposures of the clay-limestone conglomerate beds in the southwestern part of this township, but at many places the outcrops were so poor that the upper and lower layers of the Auger conglomerate could not be distinguished. For this reason the local dip of these beds at places is somewhat in doubt, but as a whole they gradually rise toward the south and west across the township. (See Pl. IV, in pocket.)

From the exposures in the SW. ¼ SE. ¼ sec. 17 to those near the center of the south line of the township in sec. 34 the beds appear to rise between 35 and 40 feet. From the northeast corner of sec. 25 to the southwest corner of sec. 34, a distance of 3½ miles, they seem to rise about 50 feet. From the NW. ¼ NE. ¼ sec. 17 to the NE. ¼ SE. ¼ sec. 31, a distance of 3½ miles, they rise about 70 feet, which seems to be about the maximum for this township. In the northwest quarter of the township they are too poorly exposed to furnish much data of value, but they appear to be practically horizontal.

The important geologic facts derived from a study of this township are (1) that the rocks dip at a very low angle from the southern and western sides toward the north and east as far north as Slough Fork of Deep Red Run, and that north of that creek the dip of the beds can not be determined with accuracy but appears to be slightly toward the east and south; (2) that fossil bones of a Permian reptile appear in place above what appears to be the upper bed of the Auger conglomerate; and (3) that the Grandfield conglomerate of Tertiary

or Pleistocene age caps the tops of the hills along the southern border of the township just above the Auger conglomerate and also bears the same relative position to the Auger lentil in exposures at a much lower level along the creek in the north-central part of sec. 17 and at other places in secs. 13 and 14. This fact is especially important because the Auger lentil and Grandfield conglomerate are separated by an unconformity representing a hiatus of at least hundreds of feet of strata, yet the two beds show practically the same structure, not only in this township, but to a large degree throughout the district.

T. 4 S., R. 15 W.

The broad, flat divide between Deep Red Run and Red River runs from east to west, north of the middle of T. 4 S., R. 15 W. The "breaks" in T. 3, just described, extend southward into parts of secs. 3, 4, 5, and 6, T. 4. The tributaries of Red River are Auger Creek on the west and Curtis Creek and Little Blue Creek on the east. Practically all exposures of Permian rocks are on or near these streams and in the "breaks" near the northern edge of the township. The southern portion of the interstream area is covered by a deep brown or reddish loose sandy soil, composed largely of wind-blown sand. Along the divide in the northern part of the township the soil is rather dark and close, though it contains some sand, but it presents a marked contrast to that of the "breaks," which is deep red in color and has a heavy clayey texture.

In the northern part of this township there is an exposure of the "speckled sandstone layer" of the Auger conglomerate near the road at about the middle point of the south line of the SE. ¼ sec. 4. At this outcrop the lower conglomerate of the Auger lentil is not exposed and may be absent. The upper layer of conglomerate is soft, thin, and red to grayish, and is embedded in red clay a few feet above the "speckled sandstone layer." At a number of places in this section the bluish-white soft cross-bedded sandstone of the Auger lentil is characteristically exposed, some cross beds having slopes of 10° to 20° that closely resemble true dips. The upper conglomerate layer outcrops at many places in the "breaks" in the W. ½ sec. 3 and E. ½ sec. 4. The "speckled sandstone layer" and associated beds also outcrop in the creek bluff at the west side of the SW. ¼ sec. 4. Between these exposures the "speckled sandstone layer" dips toward the northwest 12 to 20 feet, but this may be largely if not wholly due to the general northerly dip in this vicinity rather than to a local syncline passing through or west of the SW. ¼ sec. 4. West of this quarter section the rocks seem to rise again to a point 1 mile due west of this exposure in the east part of SE. ¼ sec. 6, where a large "break" occurs near the top of the hill. The Grandfield conglomerate, badly

weathered, caps the top of this hill. Three or four feet below it in the "break" is a soft reddish or grayish clay-limestone conglomerate which looks like the upper bed of the Auger lentil, but which may be a bed still higher in the geologic column.

The valley of Little Blue Creek in this township is very shallow, the creek being in fact no more than a shallow drain, the bottom of which is sodded in places. A bed of sandstone, grayish, false bedded and speckled, is exposed at two or more places in sec. 12 at heights less than 6 feet above the bottom of the stream. This bed is probably the "speckled sandstone layer" of the Auger conglomerate, but the identification is by no means positive. The Grandfield conglomerate or a younger gravel lies close above this sandstone wherever it is exposed on Little Blue Creek. These outcrops suggest a slight rise in the rocks upstream.

On Auger Creek near the center of sec. 18 there is exposed a massive layer of clay-limestone conglomerate, overlain by a grayish clay 6 or 8 feet thick, which contains small white limy, irregular concretions, and above that lies a bed of loose quartz and quartzite gravel. Below the clay-limestone conglomerate is a bed of bright-red clay containing roundish gray limestone concretions, which looks very like the clay below the Auger conglomerate, but no sandstone beds were found. This conglomerate is probably the lower layer of the Auger lentil. This correlation seems to be strengthened somewhat by the abrupt increase in thickness of the sandstones of the Auger lentil from northwest to southeast in this vicinity. In the NW. ¼ NW. ¼ sec. 20 the "speckled sandstone layer" of the Auger lentil, interbedded with clay-limestone conglomerate, is 3 feet thick in the bank of the creek, but pinches out entirely within 200 yards toward the northwest. This thinning suggests a local unconformity between this sandstone and a bright-red clay containing gray limestone concretions lying below it. About five-eighths of a mile a little south of east from the above exposure the Auger lentil shows the following section:

Partial section of Auger conglomerate lentil on west side of run in southeast corner of NW. ¼ NE. ¼ sec. 20, T. 4 S., R. 15 W.

	Feet.
Quaternary and Tertiary (?):	
1. Soil	5
Permian (Wichita formation, Auger conglomerate lentil):	
2. Pebbles (loose), quartz, and quartzite	1–2
3. Clay, reddish to gray, with white limy concretions	2
4. Sandstone, white, choppy, wave marked, false bedded, and thin, irregular clay-limestone conglomerate lentils	3
5. Clay, red and whitish, with some thin-bedded red clayey sandstone	1–2

	Feet.
Permian (Wichita formation, Auger conglomerate lentil)—Con.	
6. Clay-limestone conglomerate lentil, reddish to gray	½–1
7. Sandstone, thin bedded, reddish, platy, shaly, false bedded	2
8. Clay, bright red	½–1
9. Sandstone, soft, white to reddish, massive, in irregular beds	4–6
10. Concealed, probably red clay or clay-limestone conglomerate	1–2
11. Sandstone, soft, red, massive, to bed of creek	1–2
	28

Excellent outcrops of the sandstones associated with the clay-limestone conglomerate of the Auger lentil occur in the S. ½ sec. 20 and the N. ½ sec. 29. These sandstones as well as the conglomerate vary greatly in character and thickness from place to place in this area. The time available for field work was too short to permit a detailed study of the Permian beds in the "breaks." The Auger conglomerate was easily recognized wherever its horizon was noted, but at places its character is very different from that shown in its outcrop at the type locality in the NW. ¼ sec. 6, described on page 23.

On the west bluff of Auger Creek, in the central part of the NW. ¼ sec. 29, a rather hard conglomerate, consisting largely of waterworn quartz and quartzite pebbles embedded in a brownish-red limy clay matrix, is exposed at a number of places. This bed looks very much like the Grandfield conglomerate but may be younger.

The general dip of the Auger conglomerate along Auger Creek is downstream, and seems to be about 30 feet from the middle of sec. 18 to the middle of sec. 31, a distance of 3 miles. The general strike of the beds seems to range from almost east-west to northwest-southeast. From the head of the "break" in the NE. ¼ NW. ¼ sec. 32 the elevation of the uppermost hard sandstone, compared with that of the first hard beds found in shallow water wells drilled near by, toward the northeast and southeast, suggests that there is a local dip of considerable angle in that direction. There are also indications of a syncline crossing Auger Creek near the middle line of sec. 29, which further strengthens the suggestion of a local syncline trending either almost north-south, as shown by contours on Plate IV, or else northwest-southeast across secs. 29, 32, and 33.

Between the exposures on Auger Creek and the headwaters of Curtis Creek, in secs. 22 and 23, a single thick layer of clay-limestone conglomerate, very hard and compact, outcrops through the sandy soil in the road near the middle of the east line of the NE. ¼ sec. 21. This conglomerate has no quartz or quartzite pebbles and has the appearance and texture of the Permian clay-limestone conglomerates of this district. It may be either the upper or the lower bed of the Auger conglomerate or it may be a conglomerate coming higher in

the Wichita formation. If it belongs to the Auger lentil, which seems most probable, there is a dip of about 40 feet from this outcrop both to the east and to the west within 1 mile. If it is a higher clay-limestone conglomerate, this dip is probably much less or none at all, as the exposures of the Auger on Auger Creek are at practically the same elevation as those on Curtis Creek.

Near the middle of the west side of the NW. ¼ SW. ¼ sec. 23 a fine exposure of clay-limestone conglomerate from 2 to 5 feet thick occurs in the bank and bed of a small tributary to Curtis Creek. The upper layers of this bed are reddish, hard, and compact, the clay balls being small. The bottom layer contains in places many chert and limestone nodules as well as clay pebbles. This conglomerate is very irregularly bedded and very variable in thickness. It is exposed again on Curtis Creek about one-fourth mile farther southeast, in the SW. ¼ sec. 23, and appears again at the same elevation on the east side of the SE. ¼ sec. 23. In the S. ½ sec. 24, on a tributary of Curtis Creek, the "speckled sandstone layer" and other associated sandstone beds are exposed with the conglomerate beds of the Auger lentil. On the road just south of the northeast corner of sec. 25 a quartz conglomerate that resembles closely the Grandfield conglomerate was found just above the horizon of the Auger. The Grandfield conglomerate here has an altitude of about 1,095 feet above sea level. In the top of Curtis Hill, a conspicuous round hill near the center of the north half of sec. 13, less than 2 miles farther north, it has an elevation of approximately 1,174 feet above sea level, showing a rise of over 40 feet to the mile. This bed also outcrops in a small hill in the center of sec. 23, where it has an altitude of probably 1,120 feet. The general rise of the Auger lentil northwest and north along Curtis Creek and its tributaries seems to be somewhat less than that of the Grandfield. From the southeast corner of the NW. ¼ sec. 24 these beds rise about 15 feet, and in the same direction across sec. 23 the rise is probably not more than 12 feet. The slope of the surface suggests that the Auger lentil is farther below the Grandfield conglomerate in Curtis Hill than it is at the northeast corner of sec. 25.

The important facts brought out by the above discussion of the exposed beds of this township are (1) that the clay-limestone conglomerate exposed on the road near the middle of the west line of the NW. ¼ sec. 22 possibly belongs a few feet above the upper layer of the Auger conglomerate, but that there is no direct evidence to show that it is not the upper layer of the Auger; (2) that levels on the various beds associated with the Auger show a rise in them to the south and west in secs. 3, 4, 5, and 6, and a corresponding but slighter rise in them from south to north in exposures along Auger and

Curtis creeks; (3) that the Grandfield conglomerate, of Tertiary or Quaternary age, notwithstanding the fact that it lies unconformably upon the Wichita formation, of which the Auger lentil is a part, seems to conform rather closely to the structure of the latter; (4) that structurally the highest territory in the township is probably somewhere in secs. 6, 7, 8, or 9, and that there is some evidence of an anticline or structure high in parts of secs. 21 or 22, but that the trend of this anticline, if it exists at all, can not be determined because of lack of exposures in the territory farther south.

T. 5 S., R. 15 W.

Red River enters T. 5 S., R. 15 W. near its northwest corner and flows south of east through secs. 6, 5, 9, 10, 14, 13, and 12. The territory south of the river was not examined. Permian beds are exposed in this area at a few places along the river bluff in secs. 5, 6, and 9. The Auger conglomerate outcrops near the base of the river hill at a point in the SW. ¼ SE. ¼ sec. 5, where it is at an elevation of about 1,041 feet. This shows a dip of about 36 feet toward the southeast in less than 2 miles from the exposure near the center of sec. 31, T. 4 S., R. 15 W. Sandstones of the Auger lentil outcrop at many places along the base of the bluffs from this point for almost a mile toward the northwest in secs. 5 and 6, but the exposures are poor. In secs. 9 and 10 there are a few scanty outcrops of red clay, a reddish thin-bedded impure sandstone, and a thin bed of clay-limestone conglomerate, which could not be correlated. The general appearance of these exposures suggests a slight rise of the beds toward the east from some point near the southeast corner of sec. 5, but there are not sufficient outcrops to make this at all certain.

The remainder of this township toward the east and northeast is covered deeply by dune sand, and no outcrops of Permian rocks were found in it.

Attention might be called to a deposit of quartz and quartzite gravel at the base of the dune sand, overlying red nodular clay, in the river bluff near the southwest corner of sec. 4. The gravel here is locally somewhat cemented into an indurated bed, but a short distance to the east it is rather loose. This bed is probably between 40 and 65 feet above the water of the river and between 1,050 and 1,075 feet above sea level.

T. 5 S., R. 14 W.

All of T. 5 S., R. 14 W., except sec. 6 and portions of secs. 4, 5, 7, and 8 lies in and south of Red River and has not been examined for this report. No exposures of Permian rocks are known in it north of the river, the entire surface being covered by dune sand.

T. 4 S., R. 14 W.

Red River cuts across the southern parts of secs. 33, 34, 35, and 36 in the southeastern part of T. 4 S., R. 14 W. This area is drained by Big and Little Blue creeks, Curtis Creek (tributaries of Red River), and by a number of small streams flowing northward into Deep Red Run.

Except along the larger streams and in a few "breaks" adjacent to them, the surface is covered by a deep sandy to fine soil composed largely of wind-blown material. A strip of land from 1 to 2 miles wide along Red River is covered by sand dunes or by a deep mantle of wind-blown sand.

The most southern outcrop of Permian rocks on Curtis Creek is in the west bank of the creek, in the SE. ¼ SW. ¼ sec. 30. Here about 5 feet of red clay at the base of the bluff is overlain by 2 or 3 feet of reddish thin-bedded clayey sandstone, above which is 2 feet of soft lumpy clay-limestone conglomerate. This bed contains no quartz pebbles but is doubtfully correlated with the upper part of the Auger conglomerate. It has an elevation of 1,063 feet and is overlain by some red clay, above which is a layer of loose pebbles, largely quartz and quartzite, overlain by loose sand. This bed of pebbles has a distinctly younger appearance than the Grandfield conglomerate. The upper conglomerate of the Auger lentil and its associated sandstone beds outcrop in the south bank of Curtis Creek near the center of the W. ½ sec. 30. This conglomerate has an elevation of about 1,062 feet. Here also the Permian beds are overlain by the layer of quartz and quartzite pebbles underlying wind-blown sand.

In the NE. ¼ sec. 30 two outcrops of the same bed of clay-limestone conglomerate occur. One of these is near a small pond in the northwest corner of the quarter section, where the conglomerate is close, hard, grayish to reddish, and resembles closely the lower bed of the Auger conglomerate where best developed. It has an elevation of about 1,078 feet. The other outcrop occurs in the road on the east side of the SE. ¼ of this quarter section. It is here reddish to grayish, very close and compact, and seems to be in two layers, having a total thickness of possibly as much as 6 feet. Its elevation is approximately 1,100 feet above sea level. This bed forms a beautiful dip slope between the two outcrops, a distance of almost half a mile. At the residence just north of this outcrop in the NE. ¼ sec. 30 a well over 40 feet deep, located on the hill at a slightly higher elevation than the outcrop, is in red clay, showing no trace of clay-limestone conglomerate or sandstone. A few feet away and at about the same elevation another well found 4 or 5 feet of clay-limestone conglomerate and, at a depth of from 5 to 12 feet from the surface, a soft gray sandstone containing many small black specks. A shallow well

about 150 yards north of this point shows clay-limestone conglomerate and gray sandstone beds at a shallow depth. These data suggest strongly that the clay-limestone conglomerate outcropping at an elevation of about 1,100 feet is the lower layer of the Auger lentil and that there is a dip in it of probably 35 feet from the middle of the east line of the NE. ¼ sec. 30 southwest to Curtis Creek, a distance of less than three-fourths of a mile. A poor exposure of clay-limestone conglomerate, which seems to be the same as that described above, occurs in the road near the southeast corner of the NE. ¼ NE. ¼ sec. 29, where it has an altitude of about 1,085 feet above sea level. About half a mile north-northwest of this outcrop, on the south bank of Little Blue Creek, there is a peculiar grayish lumpy clay-limestone-sandstone bed which can not be definitely correlated; but its association with gray sandstones and bright red clay of Permian age a short distance farther to the east suggests that it is probably the basal bed of the Auger lentil. This outcrop has an elevation of 1,056 feet. Within one-fourth mile toward the east this bed and its accompanying sandstone layers disappear. They either grade into sandy, nodular, red clay or are cut out by a local unconformity. From this exposure eastward, in secs. 21, 22, 23, 27, and 28, red nodular clay and thin fragments of clay-limestone conglomerate are the only Permian rocks outcropping. At a number of places along this part of Little Blue Creek is a bed of quartz and quartzite pebbles, which, though somewhat indurated at places, is evidently younger than the Grandfield conglomerate.

A number of exposures of the Permian beds were found along the sides of the valley of Little Blue Creek in secs. 20, 17, 18, and 7. Most of these outcrops are such as to leave the identification of the beds somewhat in doubt, but at a few places the Auger conglomerate seems to be fairly typically exposed. At one of these places, in the east bank of the creek, in the SW. ¼ SW. ¼ sec. 17, irregularly bedded grayish to reddish sandstones contain a rather thin variable bed of soft reddish clay-limestone conglomerate. These beds lie very unevenly upon red clay and are overlain unconformably by a quartz conglomerate that resembles closely the Grandfield, and this, in turn, is overlain by a dark to bluish or grayish clay containing small white limestone concretions. The layer of clay-limestone conglomerate has an elevation here of about 1,064 feet. There is a local thickening of these sandstone layers in the NE. ¼ SE. ¼ sec. 18, where they were quarried in a small way for building stone. At this place they have an elevation of 1,075 feet. Northwest of this location, in secs. 18 and 7, poor outcrops of clay-limestone conglomerate and a quartz conglomerate which resembles the Grandfield were seen at a few places, but most of these could be definitely correlated.

On the east bank of Big Blue Creek, near the center of the SE. ¼ sec. 26, a layer of grayish clay-limestone conglomerate, from 1 to 2 feet thick, was observed just above creek level. In this bed fragments of fossil bones were found. It has an elevation of about 996 feet above sea level. It is overlain for 5 or 6 feet by soft whitish clayey sandstone layers interbedded with red clay, and above this is red to purplish clay about 30 feet thick, with "twisted or knotted" limestone concretions, and at the top of the bluff is about 25 feet of loose brownish sand. At places a little farther north a bed of coarse quartz and quartzite conglomerate, cemented by lime into a reddish hard mass, 1 to 5 feet thick, lies near the base of the wind-blown sand. This conglomerate resembles very much the Grandfield conglomerate, though it may be reworked material from that bed. At this place the Auger lentil could not be identified with certainty. The clay-limestone conglomerate noted above as carrying fragments of bones may be the upper layer of the Auger and may lie at the horizon of the bones found in the NW. ¼ NW. ¼ sec. 28, T. 3 S., R. 15 W. However, it is most probably a clay-limestone conglomerate underlying the bright-red clay bed seen at a few places about 40 feet below the Auger lentil. This outcrop suggests a general dip toward the east. About 100 yards north of the above exposure, near the north end of a high bluff on the east side of Big Blue Creek, there is a rather poor exposure of dark, limy, ferruginous sandstone which seems to dip at a high angle toward the north. This dip is also strongly suggested by poor exposures of clay-limestone conglomerate and by divisions in the beds of clay. In the short time at his disposal the writer was unable to determine with certainty the structure of the rocks at this place.

Near the southern edge of the NE. ¼ NE. ¼ sec. 35 several rather thick beds of whitish to reddish sandstone alternating with red clay outcrop for 100 yards along the west bluff of Big Blue Creek. The writer was unable to identify definitely these beds. They are very irregularly bedded and range from massive to thin bedded. The bedding planes show a decided dip toward the north, the angle being greatest at the southern end of the exposure. The writer is inclined to believe that these sandstone beds underlie the Auger conglomerate, and that they dip toward the north and pass below Big Blue Creek, a short distance upstream. If this is true, the structure of the rocks is similar to that shown by the contours on Plate IV. A few poor outcrops of massive grayish sandstone, which could not be correlated with the Auger lentil, were seen a few feet above the river bluff in secs. 34, 35, and 36. This sandstone seemed to be practically horizontal.

No outcrops of Permian rocks were seen along Big Blue Creek in sec 23, but on the west side of this creek near the southwest corner of

the SE. ¼ SE. ¼ sec. 14 a good outcrop of the clay-limestone conglomerate of the Auger lentil occurs at an elevation of 1,039 feet above sea level. The conglomerate is here overlain by loose clayey stream gravel and underlain by the bluish white and speckled sandstone layers of the Auger lentil, the typical bright-red clay lying below. A few yards farther west, in the same outcrop, the overlying stream gravel cut out the Auger lentil and lies unconformably on the bright-red clay.

At the southwest corner of sec. 13 the clay-limestone of the Auger lentil outcrops in a massive layer at the top of a small break at an elevation of 1,048 feet. At an outcrop about one-fourth mile to the northeast it has an elevation of 1,060. At this place and at an outcrop near the center of the NW. ¼ SW. ¼ sec. 13 the bluish-white and speckled sandstone layers accompany the clay-limestone conglomerate. At the latter outcrop the conglomerate has an elevation of 1,053 feet. These four outcrops show a local rise in the beds toward the east at the rate of probably 40 feet to the mile. A doubtful outcrop of the conglomerate of the Auger lentil occurs in the railroad cut on the east bluff of Big Blue Creek, at an elevation of 1,045 feet. The clay-limestone of the Auger lentil outcrops on the west bank of this creek 150 yards south of the north line of sec. 14, also just south of the road across the east fork of Big Blue Creek at the north side of sec. 13, and again about 300 yards north of this crossing, on the west side of the creek. These outcrops are, respectively, at elevations of 1,055, 1,049, and 1,052 feet. Near the northwest corner of the SE. ¼ SW. ¼ sec. 12 is an outcrop of typical Grandfield conglomerate which contains many quartz and quartzite pebbles and stands at an elevation of 1,045 feet. Either this conglomerate lies directly upon the Auger lentil or the latter is cut out entirely by the unconformity. Some of the upper sandstone beds of the Auger are exposed along Big Blue Creek in the southeastern part of sec. 11, and the clay-limestone conglomerate probably lies just below the bottom of the stream to the north edge of this section, where it again outcrops at an elevation of 1,058 feet. About a mile north-northeast of the above outcrop, near the middle of the north line of the NW. ¼ sec. 1, a speckled sandstone bed inclosing a thin layer of clay limestone conglomerate closely resembling the conglomerate of the Auger lentil stands at an elevation of 1,102 feet above sea level.

In sec. 15, on a large tributary flowing into Little Blue Creek from the north, Permian rocks are exposed at a number of places. The most southern outcrop of the Auger conglomerate found on this tributary is on its west side about 50 yards south of the north line of sec. 22, where it is at an elevation of about 1,059 feet. Near the northeast corner of the SW. ¼ sec. 15 thick beds of the bluish-white

and "speckled" sandstones of the Auger lentil, inclosing three layers of clay-limestone conglomerate, outcrop at an elevation of about 1,064 feet. The sandstone is here very irregularly bedded and seems to lie unconformably on red clay. Other exposures of the same beds along this creek northward to the section line stand successively 1,069, 1,078, and 1,079 feet above sea level. This creek forks near the center of sec. 15, and on the west fork near the east side of sec. 16 the Auger conglomerate is exposed a few feet above stream level at an elevation of about 1,082 feet and is capped by a typical deposit of the Grandfield conglomerate, which seems to form a dip slope to this point from its outcrop on the ridge at the west side of sec. 16. Reworked gravel from this bed was seen at many places along the creek in sec. 15. The Grandfield conglomerate is also exposed in a shallow railroad cut east of the road in the NW. ¼ sec. 10 at an elevation of 1,110 feet. It also outcrops at an elevation of about 1,081 feet in the east bank at the forks of the creek, at a large pond in the SW. ¼ sec. 10. At its type locality in the southeastern part of Grandfield, the Grandfield conglomerate seems to form a thin layer at or near the top of the hill. Generally it is not well exposed here except on the road southeast of the town, but it has been encountered at many places in digging storm cellars and is usually a hard reddish conglomerate containing many quartz and quartzite pebbles held together by a limestone-clay matrix. In the southeastern part of Grandfield this conglomerate has a maximum elevation of between 1,145 and 1,155 feet.

On several small streams which flow northward to Deep Red Run from Grandfield in secs. 4 and 5 are a number of outcrops of the Auger lentil. One of these outcrops is in a small ditch on the south side of the railroad a short distance west of the water tank at Grandfield. Here, at the base, there is a bed of bluish-white sandstone, which contains many small black specks and which is overlain by 4 or 5 feet of reddish thin-bedded laminated sandstone, at places false-bedded. These beds resemble very much the sandstones of the Auger lentil. They are overlain by red clay containing residual quartz gravel from the Grandfield conglomerate. Less than half a mile north of this exposure the "speckled sandstone layer" overlies a thin reddish clay-limestone conglomerate believed to be the lower layer of the Auger conglomerate lentil. At no exposure in sec. 5 is the Auger lentil typically exposed, the lower layers of sandstone and the clay-limestone conglomerate beds being either unusually thin or absent altogether. Traced northward into T. 3 S., R. 14 W., these beds seem to assume their normal thickness, outcropping along the bluffs of Deep Red Run. The speckled bed near the water tank at Grandfield has an elevation of about 1,097 feet. From this point the dip is between 20 and 30 feet to the north line of the section. Per-

mian beds consisting largely of red clay outcrop in places in secs. 34 and 36, but at none of these could the Auger lentil be definitely recognized.

The important geologic facts regarding this township brought out in the above description are (1) that there is a general low dip toward the south from the most northerly exposures of the Auger conglomerate on Big and Little Blue Creeks and their tributaries; (2) that this southerly dip is very probably interrupted by a low anticline passing south of east through parts of secs. 19, 20, 29, 28, 27, 33, 34, 35, and 36, or 20 and 25, as indicated by the elevation of the Auger conglomerate in and near secs. 29 and 30 and by the probable dip toward the north of the sandstone near the mouth of Big Blue Creek; (3) that the beds are in general higher toward the west and north than toward the east and south and that the axis of an anticline trending roughly east-west seems to lie somewhere between the exposure in sec. 15 and those in sec. 5; and (4) that the Grandfield conglomerate, though lying unconformably upon the Wichita formation, which includes the Auger conglomerate lentil, shows the same general structure as the latter, and also has a dip of probably 55 or 60 feet in the first mile and a half southeast of Grandfield, suggesting that there may be a similar dip in the Auger lentil in this locality.

T. 3 S., R. 14 W.

T. 3 S., R. 14 W., is drained by Deep Red Run, which flows from west to east. Its valley and the valleys of its tributaries are broad, flat, and alluvium-covered. The interstream areas are smooth and fairly level and are covered with a thick layer of fine sandy to stiff reddish and dark soil.

All the exposures of the recognized Permian beds occur along the valley bluffs and in a few breaks adjacent to them. The Auger conglomerate is well exposed at a number of places on the south bluffs of Deep Red Run. A section of a typical outcrop of the Auger in the NE. ¼ sec. 27 has been given on page 24. About a mile west of this place the massive speckled sandstone of the Auger lentil outcrops in a large break near the middle line of the west side of sec. 27 at an elevation of 1,069 feet, the lower clay-limestone conglomerate being at about 1,065 feet. One-half mile farther west a poor outcrop of clay-limestone conglomerate, doubtfully correlated as belonging to the Auger lentil, has an elevation of 1,044 feet. Less than a half mile south of this exposure, in the NW. ¼ SE. ¼ sec. 28, the "speckled sandstone" has an elevation of 1,050 feet, the clay-lime conglomerate being thin and poorly exposed. About three-fourths mile farther south, in the S. ½ NE. ¼ sec. 33, the conglomerate and accompanying sandstones of the Auger lentil outcrop in a number of small breaks at elevations ranging from about 1,059 to 1,065 feet above sea level.

Near the township line, in the SW. ¼ SW. ¼ sec. 34, the "speckled sandstone" bed and clay-lime conglomerate of the Auger lentil is found in a shallow well at 7 to 12 feet from the surface and at an elevation of about 1,083 feet.

On the south side of the valley of Deep Red Run, at the western edge of sec. 28, the conglomerate and sandstones of the Auger lentil are revealed by a cut made for the road, at which place the top of the conglomerate is 1,031 feet above sea level. Between this point and the exposure on the west side of a tributary valley to Deep Red Run from the south near the middle of sec. 29 there is a rise of about 16 feet in the Auger lentil. Along this tributary the beds rise continuously toward the south through secs. 29 and 32. The top of a typical section of these beds near the southern border of the SE. ¼ sec. 32 is at an elevation of about 1,070 feet. The rise of these beds, as has been shown in the discussion of T. 4 S., R. 14 W., continues to the town of Grandfield, a mile farther south, showing a total dip of between 60 and 70 feet northward from the station at Grandfield to the valley of Deep Red Run.

Near the center of the SW. ¼ sec. 20 two outcrops of massive gray sandstone beds occur along the southern bluff of Deep Red Run at elevations about 1,052 feet. Near the southeast corner of sec. 19 there is a fine outcrop of Auger lentil at which the "speckled sandstone layer," accompanying the lower portion of the clay-limestone conglomerate, is at an elevation of 1,047 feet. This exposure occurs in the bank of a small tributary to Deep Red Run and in an adjacent break, the vertical section being about 20 feet. At the base of this section is about 5 feet of reddish, irregular-bedded sandstone which has the appearance of being overlain unconformably by red clay, in which occur two or three thin layers of white and gray sandstones and clay-limestone conglomerate, some of which are smooth bedded, the other layers being very irregular bedded and variable in thickness. At another place in this break, about 12 feet above the base of the section, there is exposed about 2 feet of a soft bluish-white sandstone showing a characteristic cross-bedding, which in most outcrops of the bed has the appearance of being a true dip. At this place the layers slope toward the southwest at an angle of 10° to 15°. This bed is is overlain by 2 to 3 feet of red clay which has above it about 5 feet of cross-bedded sandstone, which is in turn overlain by about 15 feet of bright-red clay containing roundish clay-limestone concretions. Near the top of the break on the south side of the road at this place the upper layer of the Auger conglomerate outcrops as a rather massive bed of clay-limestone conglomerate, at an elevation of 1,067 feet. This conglomerate outcrops again near the middle of the east line of the NE. ¼ sec. 30, where it has an elevation of 1,071 feet. It is exposed at many places near the center of sec. 30, the best outcrop

being near a pond in the southwest corner of the NE. ¼, where it has an elevation of 1,055 feet.

In the southern part of sec. 30 the Auger lentil becomes very thin and is poorly exposed in the shallow breaks. A doubtful exposure of the upper layer of the Auger conglomerate in the SE. ¼ SW. ¼ of this section, at an elevation of 1,051 feet, suggests a continuation of the dip from northeast to southwest across this section. Near the center of sec. 31 is a poor exposure of gray and red sandstone and a thin layer of clay-limestone conglomerate, which is doubtfully correlated as Auger lentil. This clay-limestone has an elevation of about 1,076 feet and shows a slight dip toward the northeast.

In the southeastern part of this township the lower clay-limestone conglomerate of the Auger lentil is at many places unusually thick and massive. At one of the outcrops in the southwest corner of the NE. ¼ sec. 26 this bed has a total thickness of 5 or 6 feet and at places forms a low bluff along the valley side. It is here very hard, reddish to gray in color, contains a few fossil bones, and stands at an elevation of 1,047 feet. A short distance northeast of this exposure the clay-limestone conglomerate bed is underlain by 8 or 10 feet of massive irregular-bedded sandstone, a layer of which contains the characteristic black specks of the "speckled sandstone layer" of the Auger lentil.

Near the southeast corner of the NW. ¼ NW. ¼ sec. 35 the Auger lentil is typically exposed in the east bank of the small run, at an elevation of 1,062 feet. The upper portion of this bed is in poor outcrop about one-half mile farther southeast, where it has an elevation of between 1,070 and 1,080 feet.

In the road near the middle line of the south side of the SE. ¼ sec. 35, a clay-limestone conglomerate thought to belong to the Auger lentil outcrops. This has already been mentioned as being at an elevation of about 1,096 feet, showing a rise of about 34 feet in this bed toward the southeast within a distance of a mile. The outcrop of the "speckled sandstone layer" and clay-limestone conglomerate at the southern border of the SE. ¼ SW. ¼ sec. 36, at an elevation of 1,102 feet, was described under T. 4 S., R. 14 W.

About three-fourths mile due north of this exposure, near the center of the NW. ¼ sec. 36, some soft bluish-white sandstones were seen with soft beds of clay-limestone conglomerate that are very doubtfully correlated with the upper portion of the Auger lentil. If this correlation is correct the conglomerate shows considerable change from the adjacent exposures to the west and it also shows a dip of 60 feet toward the north from the southern border of the township.

In the western part of the NE. ¼ sec. 25 a very poor exposure of clay-limestone conglomerate occurs at the top of a small break at an altitude of 1,031 feet. This may possibly be the lower conglomerate

bed of the Auger lentil. Near the southeast corner of the SE. ¼ sec. 24 on the east bluff of a large tributary to Deep Red Run a fine outcrop of the conglomerate of the Auger lentil stands at an elevation of 1,030 feet. About a mile northwest of this exposure, in the NE. ¼ NE. ¼ sec. 23, typical clay-limestone conglomerate of the Auger lentil, accompanied by the "speckled sandstone layer," occurs on the east bank of Deep Red Run, where it ranges in elevation from 1,014 to 1,025 feet above sea level, the dip being to the north. About three-fourths mile almost due west of this exposure, near the northwest corner of sec. 23, the conglomerate of the Auger lentil outcrops in a low hill at the edge of the valley at an elevation of 1,036 feet. This bed may be traced for some distance to the west and is everywhere accompanied by bluish-white and speckled sandstone layers underlain by bright red clay containing clay-lime concretions. About 1¾ miles due west of the above exposure, on the north line of the NW. ¼ sec. 21, the Auger conglomerate is at an elevation of 1,020 feet. In the NE. ¼ SW. ¼ sec. 18, on the south bank of the Middle Fork of Deep Red Run, a fine outcrop of Auger conglomerate has an elevation of 1,036 feet. No outcrops of this conglomerate were found in the northwest quarter of this township north of the two exposures named above in secs. 21 and 18. A lime-sandstone and an impure sandy clay-lime conglomerate, doubtfully identified as the Auger lentil, occur near the middle part of the northern border of the NW. ¼ sec. 14, at approximately 1,044 feet. About a mile eastward on the same line, just south of the road, the lower portion of the Auger lentil outcrops at an elevation of 1,013 feet on the east side of a tributary to Deep Red Run from the north. At this place a quartz-conglomerate having very much the appearance of the Grandfield conglomerate cuts out the upper portion of the Auger lentil and a little farther south the Auger lentil is absent, the Grandfield being in contact with the bright-red clay below. No elevations were obtained on the Auger lentil farther north in this township, but it is well exposed on the bluffs in the NW. ¼ sec. 10 and in a number of places in the E. ½ sec. 3, the highest outcrop being on the north line of the NW. ¼ NW. ¼ sec. 2, where it is only a few feet below the top of the ridge and probably at an elevation between 1,090 and 1,110 feet above sea level. Along this line of exposures in secs. 10, 3, and 2 the Grandfield conglomerate immediately overlies the Auger lentil and forms a low bench along the hillsides. No other exposures were seen in sec. 2 or in sec. 11, but from the character of the outcrops to the west it seems very probable that the broad, low, dome-like hill in the central part of sec. 2 is capped by the Grandfield conglomerate, the Auger lentil lying below, and that the broad, even slopes to the south. southeast, and for a short distance to the west are really dip

slopes on the Grandfield conglomerate. In the northern part of sec. 1 the Grandfield conglomerate is exposed at a number of places and the character of the topography suggests strongly that it underlies the surface at a very shallow depth over the southern part of sec. 1 and over all the interstream area of sec. 12 to a point where it outcrops at creek level in the NE. ¼ NW. ¼ sec. 13, as described above.

All the evidence cited above and found in the field shows that the rocks in the southern portion of this township south of Deep Red Run dip to the north. This dip probably does not average more than 20 or 25 feet to the mile, but locally it may range as high as 50 or 60 feet to the mile. The strike of the rocks appears to be in general east and west. North of Deep Red Run the structure of the Auger conglomerate is not well known, because of the few exposures in that area. The outcrops that were found indicate strongly that from the vicinity of the valley of Deep Red Run the Permian beds, as well as the Grandfield conglomerate, rise to the north, the valley of Deep Red Run marking roughly the position of a syncline having a general east-west trend and pitching slightly toward the east. Here, as elsewhere, the Grandfield conglomerate shows the same general structure as that of the Permian rocks, though it is clearly unconformable on these beds.

T. 3 S., R. 13 W.

Deep Red Run enters T. 3 S., R. 13 W., from the west near its middle and flows south-southeast, leaving it about 1¼ miles north of its southeast corner. The valley of the run is from three-fourths of a mile to a mile wide, very flat, and alluvium covered. A number of large tributaries enter this stream from the north and the south, and the Auger lentil is at many places exposed on them. The clay-limestone conglomerate beds of the Auger lentil are relatively very thick and massive over most of this township, especially in the southern portion. The upper conglomerate layer ranges from less than 10 feet to probably as much as 15 feet above the lower, which is embedded in the "speckled sandstone layer." A typical exposure of the upper layer occurs near the middle of the south line of the SW. ¼ sec. 32, where it is 2 to 4 feet thick, reddish, and contains clay pebbles, the largest an inch in diameter, and also some fragments of bones. At this point it has an elevation of 1,062 feet. It is exposed again a short distance north of the center of sec. 31, where it has an elevation of 1,068 feet. From this point the conglomerate dips northeastward and is typically exposed near the eastern edge of the SW. ¼ SW. ¼ sec. 29 at the top of a break, where it has an elevation of 1,038 feet, showing a dip of 30 feet in about three-fourths of a mile. Between these two exposures, in the central part of the NE. ¼ sec. 31 and in the SE. ¼ SE. ¼ sec. 30, the lower conglomerate of the Auger

lentil and its accompanying sandstones are exposed at several places at elevations ranging from 1,026 to 1,035 feet. The upper conglomerate is also well exposed near the top of the hill in the NW. ¼ SW. ¼ sec. 33, where it stands at an elevation of 1,072 feet. A little over one-half mile due north of this point the same bed outcrops on the hill slope to the north at an elevation of 1,059 feet, from which point it dips rapidly to the north to an elevation of 1,020 feet near the south line of the NW. ¼ sec. 28 and about 150 or 200 yards southeast of a deep well drilled for oil on the George Cabalcha farm by the Oklahoma-Electra Oil Co. A similar dip in this bed was noted from the center of the SE. ¼ sec. 33 northward to the valley of Deep Red Run, at which point the lower clay-limestone conglomerate is practically at the level of the valley. A bed of the clay-limestone that resembles the lower conglomerate of the Auger lentil outcrops near the northeast corner of the SE. ¼ sec. 20 at an elevation of 1,025 feet, but the character of the exposure at this point is such as to render this identification doubtful. West and northwest of this exposure, in secs. 20, 18, and 19, several outcrops of the Grandfield conglomerate were noted which appear to be at elevations between 1,010 and 1,025 feet.

Along a low escarpment trending northeast-southwest across the NW. ¼ sec. 19 the Auger lentil is exposed in a number of places at an elevation ranging from about 1,040 to 1,045 feet. Less than a half-mile northwest of this escarpment, on the township line, a thin bed of clay-limestone conglomerate, badly weathered, outcrops near the top of a small hill which is capped by the Grandfield conglomerate. If this is the upper conglomerate of the Auger lentil, it shows a dip toward the northeast of between 35 and 40 feet within less than half a mile. The character of the exposure, however, is such as to leave its identification very much in doubt.

In the southeastern portion of this township a fine outcrop of the Wichita formation containing the horizon of the limestone of the Auger lentil occurs on the middle line of sec. 35, about 200 yards south of its northern edge, at an elevation of 1,013 feet. This bed also outcrops on both sides of the road about 200 yards west of the southeast corner of sec. 27, where it stands at an elevation of 1,004 feet.

Traced southwestward from this exposure the limestone rises 14 feet in the first half mile and 34 feet in the first 1¼ miles and 68 feet in 2 miles to the outcrop, already described, in the SW. ¼ sec. 33. Traced southward from the southeast corner of sec. 27 this bed rises much more rapidly to a high hill on the township line a short distance east of the southeast corner of sec. 34, where it has an elevation of about 1,081 feet, showing a dip to the north of about 77 feet in 1 mile.

A number of other exposures in this vicinity show clearly that there is a well-marked dip to the north in secs. 28, 33, 34, and 35.

No outcrops of the Auger lentil were found in secs. 25 and 36 in the southeastern corner of this township, but in the SW. ¼ sec. 36 there are several exposures of a grayish thin-bedded curly ripple-marked sandstone, weathering dark or black, which in places contains considerable iron in small concretionary masses. This bed is only a few feet above the valley of Deep Red Run, and seems to correspond to a similar bed exposed farther east, which lies a short distance below the lower conglomerate of the Auger lentil. Because of its peculiar appearance this sandstone was noted in the field as the "black curly sandstone layer." No outcrop of this bed was found farther west, and it seems to grade into sandy red clay in that direction and to thicken rapidly toward the east and south, where it becomes one of the more conspicuous sandstone layers of the Wichita formation.

On a small tributary just north of the valley of Deep Red Run, a short distance southeast of the center of sec. 16, the clay-limestone beds of the Auger lentil are unusually thick. At this place the two beds of clay-limestone have a total thickness of probably 15 feet and are separated by a few feet of red clay. Just east of this outcrop, in the top of a small round hill, typical Grandfield conglomerate containing many large quartz and quartzite pebbles, held together by a reddish clay-limestone matrix, lies about 22 feet above the top of the upper conglomerate of the Auger lentil. Traced northwestward along the valley bluffs the Auger lentil and Grandfield conglomerate approach each other and within a half-mile the upper layers of the Auger lentil are cut out by the Grandfield, and half a mile farther northwest all the Auger seems to have been cut out and the Grandfield lies directly on the bright-red clay below the horizon of the Auger.

Southeastward from the exposure near the center of sec. 16 the Auger lentil outcrops at many places along the low bluffs to near the center of the NE. ¼ sec. 22, where it is again cut out by the unconformity between it and the Grandfield conglomerate, which is found unconformably on red clay at an horizon below the Auger. From this point to the eastern edge of the township on the north side of the valley of Deep Red Run the Auger lentil is not exposed, the Grandfield conglomerate being present at a number of places at altitudes only a few feet above the valley.

A large tributary to Deep Red Run from the north flows through secs. 2, 11, 14, and 23, and on it a few outcrops of the Auger lentil were seen in the northern portion of sec. 14 and the western parts of secs. 11 and 2. The altitude of this conglomerate above sea level was obtained at only two places along this stream. One of these,

taken on an exposure in the NW. ¼ NW. ¼ sec. 14, found the bed at an altitude of 1,012 feet. The other place, in the NW. ¼ NE. ¼ sec. 14, has an elevation of 1,000 feet above sea level. These outcrops show a general rise of the Auger lentil toward the north at a very small angle, keeping a few feet above stream level to the northern edge of the quadrangle. At an exposure in the central part of sec. 16 the upper layer of the Auger is at an elevation of about 1,029 feet. On the northern border of this section, near the middle, it is at a height of 1,043 feet. One-half mile west of this exposure, at the northwest corner of sec. 16, the Grandfield conglomerate has an elevation of about 1,025 feet, and about three-eighths mile still farther west, on the section line, a typical exposure of the Auger lentil occurs at an elevation of 1,004 feet. Near the south side of the NE. ¼ NE. ¼ sec. 8 a fine outcrop of the lower clay-limestone conglomerate of the Auger lentil, accompanied by the "speckled sandstone layer," is at an elevation of 1,038 feet. These beds rise slowly toward the central part of sec. 4, where they have an elevation of about 1,043 feet. A number of outcrops of the Auger lentil were found in the NE. ¼ NW. ¼ sec. 8 and the SE. ¼ SW. ¼ sec. 5, where the lower part has an elevation of about 1,015 to 1,035 feet and the upper a maximum elevation of about 1,045 feet. From this vicinity to the northern edge of secs. 5 and 6 there appears to be a slight rise in the beds, though no elevations were determined. Near the northwest corner of the NE. ¼ sec. 18, a few feet above the flood plain of Deep Red Run, a good outcrop of the lower layers of the Auger lentil, underlain by bright-red clay and overlain by the Grandfield conglomerate, occurs on the east bank of a small tributary to Deep Red Run at an elevation of 995 feet. One-half mile northeast of this outcrop the sandstones of the Auger lentil show in the bed of a creek at elevations of 1,013 to 1,019 feet, showing a rise toward the northwest of probably 18 to 20 feet within one-half mile.

Along the streams over most of the area north of Deep Red Run in this district a thin bed of loose or poorly cemented quartz and quartzite gravel is exposed at many points. The appearance of this gravel suggests that it is material derived from the disintegration of the Grandfield conglomerate, but at many other places the typical indurated bed of Grandfield conglomerate is present.

The important structural features to be noted in this township are (1) the relatively steep dips of the Auger lentil toward the north over most of the territory south of the valley of Deep Red Run, especially in secs. 35, 34, 33, and 23; (2) the very definite rise of the beds northward from the valley of Deep Red Run or adjacent to it; (3) the synclinal character of this valley; (4) the general decrease in elevation of the strata, both Permian and younger, from west to east across the township; and (5) the similarity of the structure of the

Auger conglomerate lentil and the Grandfield conglomerate regardless of the fact that they are respectively Permian and probably Quaternary in age and are separated by a well-marked unconformity.

T. 4 S., R. 13 W.

The divide between the waters of Red River and Deep Red Run crosses T. 4 S., R. 13 W., from northwest to southeast. The town of Devol is located in the W. ½ sec. 20. Most of the exposures of Permian beds in this township are on the headwaters of the creeks emptying into Deep Red Run. Along the divide is a broad area in which very few outcrops occur and of the structure of which very little is known.

In the discussion of T. 3 S., R. 13 W., a description was given of an outcrop of the upper limestone conglomerate bed of the Auger lentil at the south edge of the township, near the southwest corner of sec. 32, where it stands at an elevation of 1,062 feet. One mile south-southeast of this exposure the bed outcrops again near the center line of the south side of the SE. ¼ sec. 5, where it has an elevation of 1,091 feet above sea level, showing a rise of 39 feet toward the south in about a mile. Some poor exposures of the speckled sandstone layer and accompanying lower clay-lime conglomerate of the Auger lentil occur along a small stream in the NW. ¼ sec. 8. These show a rise of the rocks to the south almost to the center of sec. 8, beyond which for more than a mile toward the south no recognizable outcrops were seen.

A low escarpment facing the northwest crosses sec. 3 from northeast to southwest. Northwest of this escarpment are a number of deep breaks and steep gullies which drain into a large tributary of Deep Red Run and in which the Auger lentil outcrops at many places. These beds have a well-marked dip toward the north in the NE. ¼ sec. 3. A similar dip to the north in sec. 4 is suggested by poor exposures in the southern portion of SE. ¼ and the NE. ¼ NW. ¼ of that section. In secs. 1, 2, 10, 11, and 12 the surface has a very smooth, even slope toward the southeast and no recognizable Auger strata are exposed, though it seems very probable that this is to a large extent a dip slope, either on the hard sandstone beds of the Auger lentil or else on the overlying Grandfield conglomerate. From the character of the exposures it seems very probable that along the edge of this escarpment in the southwestern part of sec. 3 the Auger lentil lies between 1,075 and 1,090 feet above sea level.

A dark irregular-bedded curly ripple-marked sandstone, 1 to 4 feet thick, occurs in a break on the south side of the stream near the center of the NE. ¼ sec. 11. This bed is underlain at places by a soft grayish to red clay-lime conglomerate, in places as much as 2 feet thick, which is underlain by 10 to 15 feet of bright-red to purplish

clay containing many roundish gray limestone concretions, the largest 3 inches in diameter. At other places farther west, in the SW. ¼ sec. 11, this sandstone is grayish in color and in places shows small black specks similar to those of the typical speckled bed of the Auger lentil. At other places the basal portion of this sandstone is very limy, the lime appearing in the form of small nodular masses which, being more resistant to weathering than the rest of the rock, appear as small lumps on the weathered surface of the sandstone. At still other places this sandstone is overlain by thin beds of limy, reddish sandstone, usually very thin and platy and frequently cross-bedded. In places at the top of these beds there is a thin layer of soft clay-lime conglomerate, resembling in a general way the upper conglomerate layer of the Auger lentil. The general appearance of these beds suggests that they are the Auger lentil, but greatly changed in character from exposures farther north and west, the greatest change being in the clay-limestone conglomerate, which is more sandy and which here seems to be represented by a calcareous sandstone containing a large percentage of clay. The calcareous sandstone in the SE. ¼ sec. 11 stands at an elevation of 1,032 feet. The same horizon exposed in the SE. ¼ NE. ¼ sec. 15 has an elevation of 1,036 feet, and the rocks rise very slightly toward the southeast. If the upper clay-limestone bed exposed along this stream belongs to the Auger conglomerate lentil, this bed rises between 60 and 80 feet from its outcrop in NE. ¼ sec. 15, to a characteristic outcrop of the Auger lentil on a hilltop near the middle of sec. 16, a distance of about 1½ miles. This correlation, however, is by no means certain and it is possible that the beds exposed along the creek in secs. 11, 14, and 15 underlie the Auger conglomerate. If this is true the dip between these outcrops is not so pronounced.

The Wichita formation outcrops in secs. 13 and 14 but consists largely of red clay and at no place was the Auger conglomerate lentil found in typical outcrop. A spirit-level line to a few poor outcrops along the eastern border of sec. 14 suggests that the beds are either horizontal or rise slightly toward the south.

In the SE. ¼ NW. ¼ sec. 16, the characteristic outcrop of the clay-limestone conglomerate of the Auger lentil caps the top of the small round hill mentioned above at an elevation of 1,015 feet, the underlying sandstone being present on the south slope of the hill. On this hill the conglomerate shows a pronounced dip to the southwest. A mile in that direction, in the SW. ¼ SE. ¼ sec. 17, a short distance northeast of Devol, the lower clay-limestone conglomerate of the Auger lentil and accompanying sandstone beds come to the surface in a creek bank at an elevation of 1,058 feet, showing a dip of 40 to 50 feet toward the southwest in this distance.

On the south line of sec. 20, near its southeast corner, in the east bank of a small stream, a 2-foot bed of thin-bedded platy reddish sandstone, characterized by narrow light-colored threadlike limy, concretionary raised markings on the smooth surface of the plates, outcrops at an elevation of 1,050 feet, with bright-red clay below. This sandstone is like that in the outcrops mentioned above as occurring in the SW. ¼ sec. 11, the NW. ¼ sec. 14, and the NE. ¼ sec. 15. At the last place it has an elevation of about 1,039 feet above sea level. A sandstone very similar in appearance, splitting into very thin, smooth layers with the peculiar threadlike limestone concretions on the surface, has been seen at many places near the top of the sandstone beds of the Auger lentil. Though this evidence alone is not sufficient to justify a definite correlation of these beds, the character of the underlying clay and other data suggest that this sandstone most probably lies between the horizons of the two clay-limestone conglomerates of the Auger lentil. If this is true, neither of these conglomerates is present at this point nor to the south, in secs. 28 and 29, nor still farther south, along the creek, in sec. 32. This reddish platy sandstone bed, with concretionary threads of limestone on the surface of the plates, was also recognized in a small exposure near the southwest corner of the NW. ¼ sec. 28, where it stands at an elevation of about 1,035 feet. The Permian rocks from this point south along the stream are poorly exposed because of the thick covering of wind-blown sand, and it is impossible to trace the beds from point to point along the creek. In the NE. ¼ sec. 32, near the northern edge, an exposure of massive reddish sandstone occurs a few feet above creek level. This sandstone is badly altered by weathering, showing a very uneven surface, filled with small holes, which in the weathered surface have the general appearance of fossil worm holes. The upper layer of this sandstone is usually white or light-gray in color and is the same as the bed exposed in the creek near the center of the NW. ¼ sec. 35. A little farther south there is exposed near the top of the break a thin layer of reddish thin-bedded limy sandstone, which in places is dark and ferruginous. This is underlain by a purplish joint clay about 30 feet thick, in which occur roundish concretions of burnt red ferruginous clay-limestone having a very rough irregular surface. At the base of this clay is exposed the light-colored to whitish sandstone mentioned above. A number of similar outcrops of these beds occur in the southern part of sec. 32, along the streams and in the railroad cut near the west side of the SE. ¼ of the section. No elevations were obtained on these outcrops, but they show a slight general dip toward the south. In the SW. ¼ sec. 34 the following section was seen in a large break on the east side of the stream.

Section of Wichita formation exposed in a break near the northwest corner of the SW. ¼ sec. 34, T. 4 S., R. 13 W.

	Ft.	in.
1. Wind-blown sand at top of break.		
2. Sandstone, dark, hard, limy, thin-bedded	2–	3
3. Clay, bright red	2–	4
4. Sandstone, light bluish to gray and white; very smooth bedded, thin layers 1 to 8 inches thick	2–	3
5. Sandstone, dark to black, very soft, bituminous; rarely exceeds		6
6. Conglomerate, clay-limestone, thin, soft, lumpy, very irregular; greatest thickness		10
7. Clay, bright red, with some purplish bands between and containing at many places whitish splotches a few inches in diameter; at other places it has a large number of roundish burnt red ferruginous clay-limestone concretions which have a maximum thickness of as much as 1 foot and have a very rough, irregular surface. Most of the concretions come from a thin zone near the middle of the bed	25–30	
8. Sandstone, whitish to dark red, very hard, and in places appearing to be a lean iron ore or very ferruginous sandstone	1	
9. Sandstone, very light bluish, white in a single layer, in places reddish	1–	2

This section corresponds closely in general to that already described in the NE. ¼ sec. 32. It is believed that the lumpy clay-lime conglomerate (bed 6) is equivalent to the lower clay-lime conglomerate of the Auger lentil which changes abruptly in character toward the east and southeast. The sandstone at the top of the section appears to be the same as that in the southeast corner of sec. 20, already described. This correlation strengthens the assumption that the outcrop in sec. 20 is a part of the Auger lentil. No elevation was obtained on this exposure.

In the road at the southwest corner of sec. 24 a typical outcrop of the Auger lentil, including the "speckled sandstone layer," occurs at an elevation of about 1,081 feet. At this place the clay-limestone conglomerate of the Auger appears to be very thin and sandy. The fragments of it that were seen came from a near-by well at about the horizon of the Auger, and at places thin slabs were found on the surface. South of this exposure no outcrops occur in secs. 25, 26, 35, and 36 except one near the center of the NW. ¼ sec. 35, where a massive, light gray to whitish sandstone outcrops in the bottom of the small run, with a thin layer of clay-limestone conglomerate above. This clay-limestone conglomerate was also seen on the north side of the creek near the middle of the west line of sec. 35, but its elevation above sea level was not obtained at either point. It is probable that it is not higher than 1,050 feet above sea

level. These exposures are tentatively correlated with the Auger lentil, but the beds change so much in character from west to east that it is very difficult to correlate unconnected exposures even for short distances.

The outcrops described and the elevations given above show that there is a general rise in the Auger lentil for about a mile toward the south from the northern edge of T. 4 S., R. 13 W., secs. 3, 4, 5, and 6 and in portions of sec. 8, and that the beds dip to the south-southwest from near the center of sec. 16; also that from sec. 16 toward the northeast there is a corresponding dip, which may be as much as 100 feet, to the eastern edge of the township. Also, that in the southeast quarter of the township the exposures of Permian beds are too few to give more than a general clue to the structure. The fact that the Auger lentil is exposed in the southwest corner of sec. 24 at an elevation of 1,081 feet shows that there is a dip in the beds from this point for at least 2 miles to the north and also a dip of several feet at least from this point to the outcrop near the center of the NW. ¼ sec. 35, about 1½ miles to the southwest. Between these points, in the W. ½ sec. 26, all of sec. 27, and the south halves of secs. 22 and 23, no exposures occur and the axis of the anticline therefore can not be definitely located. Southwest of Devol, in secs. 30, 29, 31, and 32, no decisive outcrops occur west of the railroad, and it is impossible to determine the structure. In the southern part of sec. 31, along the bluff of Red River, massive light-gray and red sandstones are poorly exposed at a number of places, but these exposures can not be correlated with exposures in other portions of the township and are therefore of little value in determining the structure in this part of the township.

T. 5 S., R. 13 W.

Red River enters T. 5 S., R. 13 W., at the northwest corner of sec. 6 and flows southeastward, leaving it in sec. 25. Most of the township is covered with sand hills, on which no exposures of Permian rocks were found.

In the NW. ¼ sec. 5, along the river bluff northwest of the railroad bridge across Red River, a massive, irregular-bedded light-red sandstone, locally as much as 10 feet thick, outcrops a few feet above the river level and in places is underlain by a purplish to deep red blocky clay. This sandstone can not be correlated with the Auger lentil and is probably below that horizon. It lies practically horizontal for a distance of less than a mile, in which it is here and there exposed. Along the west bank of the small creek in the SW. ¼ SW. ¼ sec. 3 a thin-bedded, compact, false-bedded sandstone, containing round black manganese concretions about an inch in diameter, is overlain by a few feet of reddish to purplish clay containing gray limestone

concretions. This sandstone seems to be the same as the one exposed at the top of the break in the SW. ¼ sec. 34, T. 4 S., R. 13 W. If this correlation is correct there is a dip of probably 30 feet toward the southeast between these exposures, a distance of about a mile.

From a point near the northwest corner of sec. 14 southeastward along the river bluff, there are several small outcrops of a white, rather massive sandstone, which stands at an elevation of 15 to 20 feet above the water of the river. Upon this sandstone lies purplish-red clay, 20 feet thick, containing peculiar roundish red clay-iron-limestone concretions like those noted in the clay overlying the white sandstone in secs. 32 and 34, T. 4 S., R. 13 W., and it is believed that this is the same horizon that is exposed there. If so, there is a dip of probably as much as 40 feet between these outcrops. Other small outcrops of sandstone extend southeastward through the SE. ¼ sec. 14 and the NW. ¼ sec. 24. These beds are best exposed, however, in the SE. ¼ sec. 24, where they form a continuous outcrop a few feet above valley level for three-fourths of a mile, which shows the following section:

Section of beds outcropping in north bluff of Red River in SE. ¼ sec. 24, T. 5 S., R. 13 W.

	Feet.
Quaternary:	
1. Sand, wind blown to top of bluffs	40–50
Permian (Wichita formation):	
2. Sandstone, light to dark, hard, limy, showing choppy ripple marks	2
3. Clay, bright red with white and gray spots and a great many peculiar round, rough-surfaced reddish clay-iron-limestone concretions, the largest 6 inches in diameter	12
4. Sandstone, soft, white to light blue, massive and at places coarse bedded	3
5. Sandstone, reddish, massive, very irregular bedded, containing limy concretionary masses 2 to 5 feet long and 1 to 4 feet thick. This sandstone contains also, 3 to 4 feet from top, a thin, irregular bedded reddish, very sandy clay-iron-limestone conglomerate similar in general appearance to that of the Auger conglomerate lentil, but very much more sandy	14
6. Débris, concealing rocks to level of valley	8
	79

The white sandstone layer beneath the bright-red clay is in almost continuous exposure for more than half a mile and lies practically horizontal except near the northwest corner of the SE. ¼ sec. 24, where it shows a slight dip toward the northwest.

No other important outcrops of Permian rocks were found in this township north of Red River.

T. 5 S., R. 12 W.

Red River enters T. 5 S., R. 12 W., in the western part of sec. 30 and describes a broad curve to the south through secs. 31, 32, 33, 34, 35, 36, 25, 24, and 13, leaving the township near the center of the east side. Most of the area is drained by Slough Creek and its tributaries, which flow from northwest to southeast through the central part of the township.

The finest outcrops of the Wichita formation in this township are along the high bluff of Red River in secs. 30, 31, and 32. A generalized section of the exposed rocks is given on pages 19–21 and a view of the bluffs in Plate V, *A* (p. 34).

These outcrops occur in a series of deep breaks that have been cut back for half a mile or less from the river, and at all places the Permian beds are overlain by dunes of wind-blown sand. With the material now available it is not possible to locate the horizon of the Auger lentil in the rocks exposed in these breaks along Red River in secs. 30 and 32. The clay-limestone conglomerate (No. 13) of the section on page 20 may possibly be equivalent to the upper clay-lime conglomerate of the Auger lentil, the lower layer belonging in the massive reddish and white sandstones, bed 15 of that section. There is, however, considerable evidence that the horizon of the Auger lentil is much higher in this stratigraphic section and that it may, in fact, be represented by either beds 7 and 8, or 5, or more nearly by beds 2 and 3 at the top of the section.

A very much more detailed study of these exposures and further correlation of them toward the east in T. 5 S., R. 11 W., will be necessary before the Auger lentil, if present at all, in these exposures can be definitely located.

From a point near the southwest corner of the NW. ¼ sec. 32 the white sandstone layer at the top of bed 15, in the section on page 20 may be traced continuously northwestward for three-fourths of a mile, in which distance it shows a dip of more than 50 feet. Beyond this point to the northwest, across the NW. ¼ sec. 30, higher sandstone beds show a decided dip northwestward, which amounts to probably as much as 50 feet within three-fourths of a mile. In the area east of the southwest corner of the NW. ¼ sec. 32, to the eastern edge of the breaks near the south-central portion of sec. 32, the sandstone beds appear to lie practically horizontal. Farther east in this township no outcrops of Permian rocks were found along the bluffs of Red River, and it is not possible to determine with certainty the trend of the anticline that crosses the river in this vicinity.

A number of small breaks on the south side of the north fork of Slough Creek in the SW. ¼ sec. 10, SE. ¼ sec. 9, and adjacent portions of secs. 15 and 16 reveal the presence of about 5 feet of coarse

grayish to yellowish sandstone bearing numerous small black specks and containing a number of hard flattish limy concretionary masses from 1 to several feet long and from 1 to 2 feet thick. Beneath this sandstone lie several feet of purplish and bright-red clay showing light-colored splotches and containing rough reddish clay-lime-iron concretions. Near the bottom of this clay is a thin, irregular layer of yellowish limy sandstone that contains fossil plants of Permian age. This sandstone in places becomes a rather thick bed of coarse yellowish sandstone, very closely resembling bed 7 of the Red River section given on page 19. These beds appear to be the same as those exposed in T. 4 S., R. 12 W., along the south side of Deep Red Run, which have been correlated with the Auger lentil. From the S. ½ SW. ¼ sec. 10 there is a local dip toward the northwest, amounting to about 15 feet in the first half mile, and a dip of probably 5 feet for the same distance toward the southeast. In the NE. ¼ NE. ¼ sec. 16 the sandstone mentioned above, at the top of the break, is exposed at an elevation of about 990 feet above sea level. Three-fourths of a mile southeastward, near the eastern edge of the SW. ¼ sec. 15, on the south bank of the creek, it is at 971 feet, showing a dip of 19 feet in about three-fourths of a mile. Between this point and the exposure on the bluff of Red River in secs. 32 and 33 no outcrops of Permian rocks are found which could be correlated with either of these. Two to three feet of cross-bedded compact platy grayish sandstone containing many black manganese concretions, the largest an inch in diameter, was seen in the west bluff of Slough Creek in the SE. ¼ SE. ¼ sec. 14, at an elevation of 930 to 940 feet above sea level, but this sandstone can not be correlated definitely with any of the beds of the Red River section (pp. 19–21), and therefore is of little value in determining the structure in this part of the township. This sandstone is underlain by about 15 feet of bright-red to ash-colored clay containing clay-limestone concretions and light splotches.

Massive light-gray to reddish sandstones form a low cliff along the river bluff in the SE. ¼ sec. 12. These beds appear to rise slightly toward the southwest, and at places above them there are exposed purplish and red clays containing rough roundish iron-clay-limestone concretions similar to those found in different places in this township and already described. These sandstones are at an elevation of about 935 to 940 feet above sea level, but their correlation with beds outcropping farther west is not certain. They probably underlie the horizon of the Auger lentil.

In the E. ½ sec. 1 a massive gray sandstone bearing many small black specks and underlain by a bright-red clay, several feet thick, containing roundish rough clay-limestone-iron concretions like those noted in other places, occurs at the top of a large break on the

south side of the stream. Above this sandstone is a darker, more reddish limy sandstone containing concretionary lenses similar to those found in the southwest corner of sec. 10, already described. At this place the beds have a general dip to the northwest, the maximum being about 18 feet within half a mile. The highest elevation of the upper sandstone bed in these exposures is near the center of the SW. ¼ sec. 1, where it is about 990 feet above sea level. It is lowest in the eastern portion of the NE. ¼ sec. 2, where it stands at an elevation of about 970 feet. There seems no doubt that these are the same beds that are exposed in secs. 9, 10, 15, and 16, and they are at about the same elevation. No outcrops of recognizably Permian beds were found farther west along the northern tier of sections. A few small outcrops of Permian beds were noted on the road between secs. 17 and 18 and at one place west of the NW. ¼ sec. 20, but no elevations were obtained on them, as the exposures are too poor to permit close correlation.

The outcrops of Permian rocks in this township are too few to enable the structure to be determined in detail. The unusual dip in the rocks toward the northwest from near the center of the NE. ¼ sec. 31 suggests the presence of an important anticline somewhere in secs. 28, 29, 32, or 33, but the trend of this fold was not determined. At first glance the facts that the three sets of outcrops in secs. 1 and 2, 9, 10, 15, and 16, and 30, 31, and 32 are on a line from northeast to southwest and that each shows a local dip to the northwest suggest that they may be exposures on the west flank of the same fold. On the other hand, Udden[1] shows what appears to be the axis of the Petrolia anticline trending northwest from Petrolia, in Clay County, Tex., and crossing the river near the northwest corner of Clay County about at the southeast corner of this township, the fold having a general trend northwest-southeast. This trend appears to be more nearly parallel with the general trend of the fold farther north, in the area studied for this report. The evidence, therefore, seems fairly evenly divided, and it is not possible to say whether the trend is northeast-southwest or northwest-southeast.

The facts that there is no direct evidence against a general northwest-southeast trend of this anticline, and that this is more nearly the direction of the large anticlines of this district, seem to favor somewhat the suggestion of a northwest-southeast trend. If this is an extension of the Petrolia anticline, which seems barely possible, it probably enters the township from the south near its middle, with a local trend more nearly north-northwest. No reliance, however, should be put on these suggestions until more evidence is available in regard to the dip of the beds in the area south of Slough Creek and

[1] Udden, J. A., and Phillips, D. McN., A reconnaissance report on the geology of the oil and gas fields of Wichita and Clay counties, Tex.: Univ. Texas Bull. 246, Pl. 1, 1912.

northeast of the exposures along the bluffs of Red River, in secs. 30 and 32. This area is covered by wind-blown sand, and the structure of the underlying Permian beds can be determined only by test wells. Perhaps detailed geologic work on the south side of Red River in Texas may throw some light on this problem. The relatively rapid rise in the rocks along the bluff toward the southeast, in secs. 30 and 32, and the horizontal position of these beds in the eastern part of the SW. ¼ sec. 32 suggest that the axis of the anticline is not far to the east or north of the center of sec. 32. The beds exposed in secs. 9, 10, 15, and 16 appear to be equivalent to beds that are at a much higher elevation in the exposures in secs. 30 and 32.

T. 4 S., R. 12 W.

The divide between the waters of Deep Red Run and those of Red River passes through the southern portion of T. 4 S., R. 12 W., in an east-west direction. Deep Red Run enters the township near its northwest corner, in sec. 5, and flows in an easterly direction, leaving it near the southern border of sec. 12. The town of Randlett is in the S. ½ secs. 28 and 29. South and west of this town, in secs. 29, 30, 31, 32, 33, and 34, no outcrops of Permian beds were seen that could be definitely correlated with other exposures in this township.

A good outcrop of the "white speckled sandstone layer" of the Auger lentil occurs on a small stream in the N. ½ sec. 35 and the N. ½ sec. 36. It is overlain by a sandstone containing dark clay-lime-sandstone concretionary lenses very similar to those found in T. 5 S., R. 12 W., and described above. At one or two places a thin, soft layer of clay-limestone conglomerate was noted above these sandstone layers. The "speckled sandstone layer" lies at an elevation of about 980 feet at the middle line between secs. 35 and 36 and of about 990 feet in the north-central part of sec. 35, and thus shows a dip of 10 or 15 feet toward the southeast within half a mile. The same beds are exposed in the NW. ¼ sec. 26, at the head of a "break" on a tributary to Deep Red Run, where the "speckled sandstone" has an elevation of about 1,005 to 1,018 feet above sea level. The Permian beds outcrop at many places in a large area in secs. 22, 23, and 24 and in the northern part of secs. 25, 26, 27, and 28, which is covered by breaks, but at few places could they be correlated and no elevations were obtained on them. In the NE. ¼ sec. 24 there is a tall butte, bordered on the east, west, and north by deep "breaks." This butte is capped by a thin layer of dark, limy sandstone, containing darker lenses of a very calcareous clay limestone and underlain by a soft light-gray sandstone showing many dark specks, which in turn is underlain by bright-red clay containing the characteristic roundish rough-surfaced clay-iron-limestone concretions seen at many places. This is believed to be the Auger lentil,

the lower clay-lime conglomerate being represented by the dark limy concretionary masses in the limy sandstone at the top of the breaks. At this place the dark sandstone layer shows an elevation of from 1,047 to about 1,019 feet above sea level, its dip being toward the north from the center of the NE. ¼ sec. 24, and slightly toward the south from this point to the southeast corner of this quarter section. The same beds outcrop about a mile farther north on a small butte in the SW. ¼ NE. ¼ sec. 13, where they are at an elevation of about 993 feet, showing a dip to the north in 1 mile of approximately 55 feet. A detailed description of this outcrop in sec. 13 is given on pages 25–26.

In the NW. ¼ sec. 21 and adjacent portions of this section the sandstone beds of the Auger lentil and some clay-limestone conglomerate are exposed near the top of a break, the bright-red clay lying below. These beds are highest at the southernmost outcrop, where they have an elevation of 1,047 feet. The dip toward the north is very uniform to a point on the east side of a small tributary of Deep Red Run in the SW. ¼ SW. ¼ sec. 9, where the dark limy bed is at an elevation of 978 feet above sea level, showing a dip of almost 6[illegible] feet in a little less than 2 miles. From the south end of this break in the NW. ¼ sec. 21 the dip toward the northeast is indicated by exposures in the SE. ¼ sec. 16, the W. ½ sec. 15, and the S. ½ sec. 10, and is about 30 feet to the mile. The dark limy layer at the top of what appears to be the Auger lentil in this township is poorly exposed in the NE. ¼ sec. 28 and the NW. ¼ sec. 27, at the head of the breaks on a large tributary of Deep Red Run, and also in the eastern part of the town of Randlett. No elevations were obtained on these outcrops, but their general position with reference to the divide indicates that they stand at altitudes between 1,000 and 1,030 feet above sea level.

A few poor exposures of the dark limy bed at the top of the Auger lentil and the "speckled sandstone layer" below it were noted on the road between secs. 19 and 20 and 17 and 20 and also at one or two places in sec. 18, on the west side of the creek. No spirit-level lines were run to any of these exposures, and the structure of the beds in this part of the township is not known except that there appears to be a general dip toward the north from near the southern portion of sec. 19.

In a break near the northeast corner of the SE. ¼ sec. 7 what appears to be the upper clay-lime conglomerate of the Auger lentil outcrops at an elevation of 984 feet above sea level. This bed is also exposed near the middle of the north line of the NE. ¼ sec. 7, at an elevation of 987 feet, and also near the southeast corner of the NW. ¼ sec. 6, at which place no elevation was obtained.

No outcrops of the Auger lentil or other Permian sandstones were found on the north side of Deep Red Run in this township.

In the NW. ¼ sec. 2, on both sides of the small tributary to Deep Red Run from the north, there are a number of fine exposures of a quartz conglomerate which in character and general appearance closely resembles the Grandfield conglomerate. It here overlies a bright-red clay, which in places shows a purplish to ashen band, contains roundish gray clay-limestone concretions, and is similar to the clay underlying the Auger lentil at a number of places farther west. This quartz conglomerate is exposed for almost half a mile along both sides of this stream and shows a slight dip toward the south. It is here only a few feet above the alluvial plain of Deep Red Run and is at an elevation of between 950 and 960 feet above sea level. Very similar exposures of this conglomerate were seen along the tributary of Deep Red Run next to the east, in the western part of the NW. ¼ sec. 1. It was also seen a few feet above valley level in the northeastern portion of the NE. ¼ sec. 9.

It will be noted from the elevations given on the upper portion of the Auger lentil of this township that there is a general and fairly uniform dip of the beds toward the north from near the divide between the waters of Deep Red Run and of Red River, which traverses the township from east to west through the second tier of sections from the southern border, and that there is some evidence of a corresponding dip from this divide toward the south, so far as indicated by the poor exposures in the southern portion of the township. On the north side of Deep Red Run there are no exposures to indicate the character of the dip of the Permian beds, but farther north there is a slight dip to the south, and it is believed that the valley of Deep Red Run in a general way lies near the axis of a broad, shallow syncline trending from north-northwest to east-southeast.

T. 3 S., R. 12 W.

Deep Red Run and its tributaries drain the southwestern half of T. 3 S., R. 12 W. Streams in the northeastern part of the township flow into West Cache Creek, which crosses its northeast corner in secs. 1, 2, 12, and 13. The Permian rocks in the central part of the township and the interstream areas are covered with a thick mantle of soil, which is seemingly composed largely of wind-blown material. The outcrops of Permian beds in this township are confined to a few small exposures of red clay and grayish sandstone beds and, rarely, thin layers of clay-limestone conglomerate. These exposures were too few to justify the running of spirit-level lines to them. A fairly typical outcrop of the clay-limestone conglomerate and the accompanying gray sandstones of the Auger lentil was found in the low break in the northern portion of the SW. ¼ sec. 8, where the lower portion of the clay-lime conglomerate is underlain by a bright-red clay containing roundish gray limestone concretions

typical of the clay underlying the Auger lentil in the type locality. A poor exposure of what appears to be the same bed was seen on the west side of the creek in the SE. ¼ NE. ¼ sec. 17. No other outcrops of the Auger lentil were found along either bank of the large tributary to Deep Red Run that flows through secs. 6, 8, 16, 17, 21, 28, and 33. Two layers of soft white sandstone, 2 or 3 feet in thickness, occur in the NE. ¼ NE. ¼ sec. 26, and what appears to be a thin clay-limestone conglomerate was found on the northern border of this quarter section. No other recognizable outcrops of Permian rocks were seen in this township, but just over its eastern edge, adjacent to the SE. ¼ sec. 13, at Rocky Ford crossing of Cache Creek, the clay-limestone conglomerate and "speckled sandstone layer" of the Auger lentil are typically exposed, together with the dark limy layer containing flattish dark hard concretionary masses, such as were seen in T. 4 S., R. 12 W. Here the lower clay-limestone conglomerate is at or near water level of Cache Creek.

Near Fairview schoolhouse, in the southeast corner of sec. 5, a number of bowlders of clay-limestone conglomerate were seen on the surface by the roadside, but it is possible that these have been hauled to this point. Thin layers of quartz gravel also were seen at a few places, but no characteristic exposures of the Grandfield conglomerate were found.

From the data cited above it is evident that the structure of the Permian beds in this township can not be definitely shown. The position of the outcrops of the Auger lentil suggests that there is a gentle rise of the rocks toward the north from the valley of Deep Red Run and also that the beds dip slightly toward the east, but at a very low angle. A long, broad ridge extends northwestward from near the center of sec. 26, passing diagonally through secs. 22, 16, 9, and 5. The character of the slopes to the east from the top of this ridge and to the south from the northern borders of secs. 26, 27, and 28 suggests that they may represent a general dip slope similar to that seen at a number of places in the townships farther south and southwest, but there is no direct evidence of this surface slope being even roughly parallel with the dip of the rocks.

T. 4 S., R. 11 W.

Deep Red Run empties into West Cache Creek in the northwest corner of sec. 17, T. 4 S., R. 11 W. The latter stream flows a little south of east and near the center of sec. 13 empties into Cache Creek, which flows southeastward into Red River. No geologic work was done north of the valley of Deep Red Run and Cache Creek in this township. Along the south side of this valley are many large breaks in which occur numerous outcrops of the Wichita formation, including the Auger conglomerate lentil. An exposure of the Auger lentil

in the NE. ¼ sec. 24, T. 24 S., R. 12 W., at an elevation of 1,047 feet above sea level, has already been described. From this point northeastward across the NW. ¼ sec. 19 there is a decided dip in the beds to a point where the Auger lentil is again exposed in some low buttes in the S. ½ SE. ¼ sec. 18, where it is less than 1,000 feet above sea level. No elevations were obtained on the key horizon in this part of the township, but there appears to be a slight dip in the beds in the southeast corner of sec. 18, which extends eastward for about 1½ miles. The steepest dip, however, is from north to south. The sandstone and clay-lime conglomerate beds of the Auger lentil which outcrop along the southern edge of the breaks in the northern portions of secs. 30, 29, and 28 dip toward the north at a rate that brings them only a few feet above valley level on the points of the hills adjacent to Deep Red Run. This dip is well shown by outcrops in the W. ½ sec. 22, where, within half a mile, it amounts to probably as much as 25 or 30 feet. In the SW. ¼ NW. ¼ sec. 22 the lower conglomerate layer of the Auger lentil and the accompanying "speckled sandstone layer," together with the soft bluish-white cross-bedded sandstone beds overlying them, are typically exposed, and beneath the sandstones is the bright-red clay, 15 to 20 feet thick, containing the characteristic roundish gray clay-limestone concretions so frequently seen in it. From this point these beds may be traced with ease along the breaks southeastward through secs. 26, 35, and 36 to the southeast corner of the township. Throughout this distance they appear to be practically horizontal, and it seems probable that this is roughly the direction of strike of the beds which dip toward the northeast from the point where they outcrop in the breaks adjacent to the Red River in secs. 32, 33, and 34. A typical section of the rocks exposed in this area is given on page 21. At the head of the large break near the center of the NE. ¼ sec. 32 a massive gray sandstone bed, beautifully exposed, shows a decided dip toward the north and northwest. The outcrop in this instance may be traced across the southwest corner of the NW. ¼, the northern portion of the SW. ¼, and in the SE. ¼ sec. 33. In this distance it shows a general rise toward the east, but the amount and exact direction of this dip was not determined. The very irregular bedding and changeable character of the sandstones outcropping in these breaks make it very difficult to determine accurately the direction and amount of the general dip by taking angles on the beds themselves. This dip can be accurately measured only by running spirit-level lines to the various outcrops and getting their elevation above sea level. Unfortunately, this work could not be extended over this area in the time available for field work.

At the time field work was done for this report a test well for oil and gas had been started near the southeast corner of sec. 30. This

well is reported to have reached a depth between 400 and 500 feet, after which drilling was suspended. The altitude of the ground at the mouth of this well is about 1,001 feet above sea level. No detailed record of it was obtained.

From the exposures in the southern part of this township it is not possible to locate closely the axis of the anticline that enters it from the west in some portion of sec. 30. It seems probable that the broad, relatively flat divide that trends almost northwest-southeast across secs. 30, 29, 32, and 33 may mark approximately the axis of this fold. From the edge of the breaks in the northern parts of secs. 28, 29, and 30 there is a fairly steep dip to the north, and it appears that the beds exposed along the northern edge of the breaks in secs. 32 and 33 are at a higher elevation than the same beds where they are exposed in secs. 29 and 36. It therefore seems probable that the well located in the southeast corner of sec. 30 is a short distance south of the axis of this fold.

T. 5 S., R. 11 W.

Only a part of secs. 1 to 7, 12, and 18 lie north of Red River in T. 5 S., R. 11 W. Exposures of Permian rocks occur in the river bluff almost across the township, but these beds have been studied only in parts of secs. 4, 5, 6, and 7. On the south side of the creek, in the SW. ¼ SW. sec. 6, these massive sandstone beds, which are believed to lie considerably below the horizon of the Auger conglomerate lentil, outcrop at an elevation of about 935 feet, or about 31 feet above the water of the river. These beds seem to show a slight dip toward the east along the river bluff in secs. 7 and 6 and the western part of sec. 5, and from that point to the mouth of a small tributary near the center of the north line of sec. 4, from which they seem to rise slightly. The structure was not studied along the river bluffs farther east. At this point the top of a "speckled sandstone layer" overlying a reddish clay-limestone conglomerate that contains many yellowish clay pebbles (beds 9 and 10, p. 22) is at an elevation of between 955 and 965 feet above sea level. There is some question as to the correlation of the Auger lentil in these exposures, and it seems possible that the dark limy sandstone containing flattish dark to black concretionary masses which outcrops at the very top of the breaks at elevations between 1,015 and 1,030 feet above sea level may be equivalent to the Auger conglomerate. Work in this portion of the township was done at the very close of the season, and sufficient time was not available to permit a more careful study of the outcrops of these sandstones with a view of correlating them with those exposed adjacent to the Auger conglomerate on the south side of the valley of Deep Red Run. This line of outcrops is important structurally, because it shows that no

definite anticline crosses the river at this point, although one is suggested by the trend of the structural "high" across the middle portion of T. 4 S., R. 12 W. It therefore indicates that the axis of the "high" may lie just north of the breaks in the southern part of T. 4 S., R. 11 W.

SUGGESTIONS TO PROSPECTORS.

Shortly after the field work was completed for this report a press bulletin was issued, which described the favorable places for test wells as follows:

In his preliminary statement to the Survey of the main results of the examination, Mr. Munn reports that an anticline appears to cross Red River in or near the SW. ¼ sec. 32, T. 5 S., R. 12 W. The dip within 1½ miles along the western limb of this fold is probably between 50 and 75 feet, the character of the rocks exposed rendering an exact measurement impossible. The trend of this fold is uncertain, but it may be stated that almost any portion of sec. 32, T. 5 S., R. 12 W., appears favorable, structurally, for oil and gas. The northwest quarter of the section seems most favorable. If an oil and gas pool is present in this vicinity it very probably extends to adjacent portions of secs. 33, 28, 29, and 31.

In T. 4 S., R. 12 W., some good exposures of Permian sandstone and clay-lime conglomerate suggest strongly that a structural "high" exists a short distance north of the town of Randlett. It is not possible at this time to outline definitely this anticline or structural dome, but it seems likely that the crest is situated somewhere in the SW. ¼ of sec. 21, the SE. ¼ of sec. 20, the NE. ¼ of sec. 29, or the NW. ¼ of sec. 28, T. 4 S., R. 12 W. The "high" may be a dome of small extent, or it may be a part of a fairly definite anticline trending eastward, leaving the township in either sec. 24 or 25. There may be a secondary structural dome in sec. 24, T. 4 S., R. 12 W., because the beds dip about 50 feet from the top of the large butte in the northeast quarter of this section to a small butte about a mile north of it, in sec. 13, and also at about the same rate toward the northeast. The structure of the rocks south of the large butte for almost 2 miles can not be determined. In the NW. ¼ sec. 26 the beds are several feet lower. The trend of this anticline is probably S. 50° or 60° E. The position of this fold was not determined in T. 4 S., R. 11 W. It seems most likely to pass across some portion of sec. 32 and 33, but it is probably becoming lower and flatter toward the southeast. The shallow test well drilled in the southeast corner of sec. 30 probably lies half a mile south of the axis of this fold. This location seems on the whole favorable for testing, but a still better one would be about 1½ miles northwest of it, as the rocks there are probably 30 feet higher structurally. If a test well is sunk near Randlett it should be located near the center of either sec. 21 or 27, T. 4 S., R. 12 W.

In T. 4 S., R. 13 W., the strata at the southwest corner of sec. 24 seems to be between 40 and 50 feet higher than they are in secs. 35 and 11. Other available data suggest that the high, long hill in secs. 22, 23, 24, 25, 26, and 27, T. 4 S., R. 13 W., is in part structural and therefore somewhat more favorable for oil and gas than portions of the adjacent territory. There seems to be little preference in a location for a test here. Probably as good a place as any would be in the NE. ¼ sec. 26.

In a general way the northwestern part of T. 4 S., R. 13 W., would appear worth a trial for oil or gas if pools are found in other areas. Secs. 8, 9, 16, and 17 are probably somewhat more promising than the adjacent ones. A small round hill in the NW. ¼ sec. 16 is capped by a thick clay-limestone conglomerate that is probably 40 feet higher at this place than at the northern edge of Devol, a mile to the southwest. It is also about 20 feet higher than at an exposure near the northeast corner of sec. 8, but its altitude at intervening points is not known. This clay-limestone conglomerate bed dips about 15 feet in the first 1¼ miles to the north from the northwest corner of sec. 8, and from that point dips about 55 feet more in the next 1¼ miles northward to the dry hole in the NW. ¼ sec. 28, T. 3 S., R. 13 W. It seems very probable that if this well had been located a mile farther southeast it would have been on the axis of the anticline that plunges steeply toward the north. So far as structure is concerned the location of this dry hole is very unfavorable, and it should not be considered a fair test for this vicinity. In fact, it is thought that test wells located in the SW. ¼ sec. 33 or on or near the high hill in the southwest corner of sec. 35, T. 3 S., R. 13 W., or in the NE. ¼ sec. 8 or the NW. ¼ sec. 9, T. 4 S., R. 13 W., will perhaps have as good chance of developing oil or gas as any part of this territory.

North of Deep Red Run rock exposures are meager. If a test well is contemplated in T. 3 S., R. 13 W., north of Deep Red Run it might as a venture be placed in the N. ½ sec. 9 or adjacent territory to the northeast.

In Tps. 3 and 4 S., R. 14 W., the principal structural feature is a "high" vaguely outlined by exposures on Big Blue and Little Blue creeks and on streams flowing north into Deep Red Run. Spirit-level lines to these outcrops show that from the divide between Red River and Deep Red Run the rocks dip rather uniformly but at a low angle to both of these streams. The exact position and character of this structural feature is not fully determined. It is probably a broad, low, irregular fold with a somewhat sinuous east-west trend and may be a continuation of the "high" in the northwest part of T. 4 S., R. 13. It seems to continue westward through portions of T. 4 S., R. 15 W. A test well in the area east of Grandfield should be located either in the north tier of sections of T. 4 S., R. 14 W., or in the southern tier of T. 3 S., R. 14 W. Probably the central part of sec. 1, T. 4 S., R. 14 W., should receive slight preference.

When the field work was being done a derrick had been built in the southwest corner of sec. 9, T. 4 S., R. 14 W., about a mile south of the station at Grandfield. This seems to be a rather favorable location for a wildcat test, though the available data are too meager to support a more definite statement.

In T. 3 S., R. 14, north of Deep Red Run, the rocks rise very gently, but the exposures are so rare as to furnish no evidence of decided folds if they exist.

There is some good evidence that a small anticline crosses Big Blue Creek in the SE. ¼ sec. 26, T. 4 S., R. 14 W., less than a mile above its mouth. The axis of this fold seems to trend almost east-west. A test in this vicinity should be located near the east-west line through the middle of secs. 26, 27, 28, and 29.

In T. 4 S., R. 15 W., the beds appear to rise at a very small angle from the east, south, and north to a broad level area in secs. 7, 8, 9, 10, 11, 14, 15, and 16, in which very few exposures occur.

The structure of T. 3 S., R. 15 W., also is not definite. The most prominent feature is a gentle rise of the rocks toward the west and southwest, across the township.

A dry hole located in the NE. ¼ sec. 9, less than a mile north of the station at Loveland, seems to be near the middle of a very broad, flat syncline in which the rocks are practically level.

Work was done in the eastern parts only of Tps. 3, 4, and 5 S., R. 16 W. Few exposures are present in this territory and but little geologic information is available regarding the structure. The character of the topography suggests a general dip toward the west from east of the middle of T. 4, but this evidence taken alone is of very little value.

According to the present incomplete data, it is suggested that the first wells in Tps. 3, 4, and 5 S., Rs. 15 and 16 W., should be located in some parts of the high, smooth prairie country south of the "breaks" in T. 4 S., R. 15 W. Also, it is suggested that any producer who may be inclined to wildcat in the Quanah district should locate on the old town site of Quanah or in the W. ½ sec. 31, T. 3 S., R. 15 W.

In offering these suggestions for the use of drillers in choosing locations for test wells ("wildcatting"), the geologists are assuming that the formations containing the oil-bearing sands in the Electra, Burkburnett, and Petrolia fields of northern Texas underlie adjacent portions of Oklahoma. This assumption is warranted, to some extent at least, by the evident continuity of the outcropping beds from one district to the other. It has been assumed that the formations containing the oil sands in northern Texas also contain the same or similar oil-bearing beds in southern Oklahoma. It is quite certain that the general structural conditions are similar in the two areas, and, on the whole, there seems to be no reason, determinable in advance of drilling, why portions of southern Oklahoma do not contain pools of oil and gas of commercial size. One object of the governmental examinations is to give the driller some aid in choosing locations for tests. The tests must be made before the question of the occurrence of oil may actually be settled. The locations mentioned as good places for wildcatting are based almost wholly on the structure or the dip of the rocks and the probable height of the oil sands here as compared with their height where they are productive in the Burkburnett, Electra, and Petrolia fields. It should be remembered that the areas suggested for tests may not be all that are favorable for tests in the region, but they are the more apparent ones brought to notice during the course of the field work. The actual difference in elevation of the probable oil sands at various points in this area can be determined only after further study of the field notes. It is believed that test wells located according to the suggestions given by the Geological Survey in this district will offer much better chances of finding oil or gas than those on locations made in the ordinary unscientific way, though it must always be borne in mind that in most new and unproved regions, even where the conditions for the determination of structure are favorable (as they are not in this region), no human agency can at present determine with certainty, in advance of drilling, whether oil or gas will be found at any given point in commercial quantities.

A more detailed study of the field notes for the complete report shows that, in the main, the above statement requires little modification to conform to the structure as mapped on Plate IV. One correction of minor importance is that the small dome in the southeast quarter of T. 4 S., R. 13 W., may prove to be much steeper on the north side than on the south, and that a secondary fold may extend southeastward from it and connect with the fold seen in the bluffs of Red River in secs. 30, 31, and 32, T. 5 S., R. 12 W.

Also, the dome mentioned as being in secs. 8, 9, 16, and 17, T. 4 S., R. 13 W., seems to be much larger and more prominent than at first stated. The structure contours on Plate IV suggest that this dome

embraces not only all or parts of the above sections, but also extends across secs. 6 and 7, T. 4 S., R. 13 W., and sec. 1, T. 4 S., R. 14 W. From this dome the contours show a broad, flat secondary anticline or structural nose jutting out toward the south and pitching steeply to Red River at the southwest corner of T. 4 S., R. 13 W. The contours show two other secondary folds, trending north and northeast, respectively. The general position of these structural "highs" was indicated in the press bulletin, but not with the definiteness given by the contour lines on Plate IV (in pocket).

The structural "high" reported in T. 4 S., Rs. 14 and 15 W., is shown by the contours to be a part of the Deval anticline, the axis of which rises to a small dome at Grandfield. The structure as mapped indicates that this dome is a favorable place for a test. A suggestion was made in the press bulletin that in T. 4 S., R. 15 W., the best location is "in some part of the smooth prairie country south of the 'breaks.'" The reason for this suggestion is illustrated by the contours on Plate IV, which show that a high, broad dome covers a considerable area in the central part of this township. In fact, so far as known, this is one of the most favorable places for oil or gas in the district. The contours show a high anticlinal nose jutting southward from the center of this dome. Unfortunately, this fold can not be traced very far in that direction because of lack of exposures. It seems probable, however, that it may extend to Red River and possibly beyond, in which case the south-central part of T. 4, R. 15 W., may be favorable for oil and gas.

The contours also show a minor anticline trending east-southeast from the above dome across the southwest corner of T. 4 S., R. 14 W. This fold appears to be low and irregular but may be large enough to afford a favorable place for the accumulation of oil and gas.

The dome in the northwest corner of T. 4 S., R. 15 W., and adjacent area in R. 16 is one of the highest in the district, and, other geologic conditions which can not be determined from the surface being equal, is one of the best locations in it for a test well. South-southwest of this dome, along the ridge between Settler Creek and Auger Creek, favorable places for tests may exist, but the available data concerning that area is too scanty to be reliable.

North of Deep Red Run the most favorable place for a test in the district is on the high hill in the N. ½ sec. 2, T. 3 S., R. 14 W. There may be several other favorable locations in this part of the district, but they could not be picked out because of lack of good outcrops.

In conclusion, the fact can not be overemphasized that favorable structure is only one of a number of equally important conditions for the accumulation of oil and gas. Among these are (1) the thickness, number, and position of beds which contain, or have contained, the organic material from which the oil and gas were derived; (2)

the stratigraphic relation of beds carrying salt water to those in which the oil and gas originated; (3) the thickness, variability, and stratigraphic position of porous lenses or irregular beds of sand that may serve as reservoirs; and (4) the structural changes through which these beds have passed since they were deposited. In fact, it seems probable that pools of oil and gas have been accumulated by the combined effect of all of the above factors or agencies working under varying geologic conditions through long periods of geologic time, together with others about which little is known. It should be remembered, however, that the accumulation of oil and gas is not fully explained by the much quoted "anticlinal theory," which accounts for the accumulation of pools of oil and gas at certain favorable places by the difference in weight of gas, oil, and salt water, where the water is under hydrostatic (still) conditions. This theory assumes that these three substances were once mixed in the rocks and that subsequently the gas, oil, and salt water arranged themselves in certain porous beds according to their respective gravities, the gas, being lightest, collecting at the tops of the anticlines, or above that part of the porous bed containing the water at places where this porous bed is overlain by an impervious one; the oil collecting below the gas; and the salt water remaining in the poro[illegible] below the oil. According to this theory, areas of close, h[illegible] in the oil-bearing stratum have offered barriers to the upward movement of the oil and gas, thus forming pools on the lower sides of the barriers. Conversely, where no salt water is present in an oil or gas sand it is assumed that both these substances have drained down the dip through the porous stratum and collected in a pool in the bottom of the syncline or on the upper side of some local barrier of impervious material. Therefore the central idea of the anticlinical theory is that the oil and gas traveled from their place of origin to their place of accumulation through the motionless interstitial water, and that their power to move was due entirely to the differences between their weights and that of the water.

Though this theory has been very successfully applied to many oil fields it has not satisfactorily accounted for (1) the closed pressure of gas pools (in some pools amounting to 1,500 pounds to the square inch); (2) the presence of oil and gas pools that completely occupy sandstone lenses which are surrounded on all sides by shale and furnish no salt water; (3) the presence of oil and gas under high pressure in porous pay streaks in sandstone of ordinary texture and porosity; (4) the presence in a dry sand of large pools of both oil and gas that do not conform to structure lines, but extend across minor anticlines and synclines alike; (5) the occurrence of pools in pay streaks differing greatly in porosity; (6) the difference in the initial closed pressure of gas wells in a given area; and many other

phenomena of a local nature, the signifiance of which can not be discussed at length in this paper. Furthermore, experimental work with oil and water in capillary tubes of glass shows conclusively that water will not displace oil placed at the bottom of the tube even if the diameter of the capillary is increased to many times that of the largest pores in the average oil sand.

The fact that the anticlinal theory does not provide a satisfactory explanation of the above-named phenomena, which are encountered in almost all fields by producers, leads the writer to believe that the idea on which it is based—namely, the accumulation through difference in gravity of gas, oil, and salt water—is wrong. On the other hand, the writer does not wish to be understood as denying the very evident fact that geologic structure has determined the position of many pools of oil and gas, but he can not believe that the known facts regarding the modes of accumulation of oil and gas justify the assumption that difference in weight of oil, gas, and water is the principal factor of accumulation.

The phenomena which the writer has observed lead him to believe that the accumulation of oil and gas in pools is due to the action of large bodies of water moving under both hydraulic and capillary pressure. If this is the true mode of accumulation, oil and gas pools of commercial size have been formed by bodies of water that moved along the bedding planes and collected ahead of or in them a portion of the oil and gas contained in the porous bed. This oil or gas may have been indigenous to the porous bed or it may have been forced into it from above or below by previous invasions of water traveling more or less vertically from water-bearing beds by capillary pressure, aided by hydraulic pressure, through the shale or other fine-grained petrologenic rock. One objection frequently raised against previous statements of this theory is that it does not seem to provide an adequate explanation of the fact that gas is generally found in the porous bed above the oil and the oil above the water. It should be remembered, however, that in a body of oil and water moving, say, horizontally, two forces act in different directions on a given globule of oil or gas. One of these forces is gravity, which tends to pull the water down and shove the oil and gas upward by an amount equal to the difference in specific gravity of the water and the oil or gas. This force is exerted in a vertical direction. The other force acting on the particle of oil or gas is that exerted by the horizontal flow of the water through the porous bed. The latter force is many times greater than the former, but the resultant of the two forces is a line slightly rising from the horizontal in the direction of the flow.

Therefore it is possible that an oil or gas particle may rise to the top of a bed saturated with water if the water is moving, and its

motion involves only kinetic friction on the oil or gas particle, whereas, if the water were still, the static friction would be far too great to permit any movement of the oil or gas, no matter what length of geologic time might be involved.

According to this theory, favorable places for accumulation are places in the porous bed that present great differences in porosity, whereby the oil is mechanically separated or strained out of the oil-water fluid, or other places where there is great variation in the rate of movement of different parts of the edge of the invading body of water, the oil being thereby confined between saturated portions of the oil-bearing bed, which have been filled by water moving in opposite directions. Pitching axes of anticlines, structural domes, monoclines of irregular trend, and places where the porosity of the oil sand changes greatly are favorable locations for trapping portions of the oil and gas accumulated by the moving water. It seems probable that much of the gas has been evolved by slow chemical change from the oil after it was accumulated into pools. This theory has been stated in greater detail elsewhere [1] and need not be repeated here, attention being called to it simply to make clearer the following suggestions to prospective operators in the Grandfield district.

The existence of an anticline at a certain location does not necessarily indicate that that spot is the most desirable for a test well. The prospector should keep in mind the fact that anticlines have relatively great length in comparison with their breadth, that the axes of folds vary in altitude from place to place, and that each fold has what may be termed a critical altitude for each oil sand, at which oil and gas are most likely to accumulate. The critical altitude of an oil sand seems to depend on its content of water, which in turn depends on many important factors, such as the regional distribution of the sand, its character—whether uniformly coarse and open, fine and close, or porous at some places and hard and close at others—the general structure of the oil-bearing rocks, and the source of the water in them and its head. Unfortunately, the value of all these factors can not be determined definitely in any region in advance of the drill. Their combined effect, however, is to cause certain portions of each oil sand to be saturated with water under sufficient head to furnish a flow into wells drilled into it, the height to which this water will rise in a well differing greatly and reaching a maximum of several hundred or even thousands of feet. The portion of a given sand most likely to be productive forms a belt of greater or less width along the margin of that part which is just saturated with water or where this water in it is under a low head. This saturated belt does

[1] Munn, M. J., The anticlinal and hydraulic theories of oil and gas accumulation: Econ. Geology, vol. 4, No. 6, Oct., 1909; U. S. Geol. Survey Geol. Atlas, Sewickley folio (No. 176), 1911. Munn, M. J., and Shaw, E. W., idem, Foxburg-Clarion folio (No. 178), 1911.

not everywhere occupy a horizontal plane in the sand out, as already stated, may vary greatly in height from place to place. Therefore the critical altitude at which pools are most likely to occur on one anticline in a given sand may be, and generally is, very different from the critical altitude for the same sand on another anticline some distance away, and also for other sands having different water conditions.

The hydraulic hypothesis of accumulation lends itself readily to the explanation of pools in and around which no water is found in the oil sand, because it assumes that the lack of porosity of the rocks surrounding oil pools is due largely to the sealing of the pores by interstitial water. The water content of a given sand, as well as the water pressure in it, may change materially with the lapse of geologic time by reason of the modification of the shape of the bed by both upward and downward movements of the earth's crust, the development of local folds in the strata, changes in the size, character, and height of the intake area from which the water is derived, climatic changes, and many other phenomena which are commonly incident to the geologic history of every region. It is therefore not safe to assume, because a given "sand" shows no water in wells sunk around an oil or gas pool in it, that this sand contains no water and that the pool was not accumulated by moving water. Where pools occur in "dry" sands—sands that show no water—it is not safe to go further than to assume that the water in the sand has little or no hydraulic head and therefore little or no pressure to force it into the wells. The very fact that oil and gas pools do exist under high pressure in porous "sands," many of which have great horizontal extent, justifies the assumption that the rocks above, below, and entirely surrounding the "pay sands" of these pools are impervious to the oil and gas; otherwise the great pressure not only would have dissipated the pool long ago, but would have been an ever-present impediment to the accumulation of such pools. It is a well-established fact, however, that the rocks which inclose these "pay sands" contain considerable pore space, ranging from probably 1 per cent up to perhaps 10 per cent or more of the rock mass. Therefore the only conclusion possible is that the pores of the rocks in contact with "pay sands" of oil and gas pools must be filled temporarily with something that renders the rocks impervious to oil or gas under high pressure. The only substance, apparently, which will universally satisfy this requirement is water, and it seems safe to assume that the rocks surrounding oil and gas pools are always saturated with water, and that where no water is obtained from the oil sands in wells surrounding pools the head or pressure of this water is too small to force it through the pores of the rock in

appreciable quantities because of the very great resistance due to friction. This pressure may have been many times greater at some other geologic period—sufficient, in fact, to force the water through the rocks and to accumulate the pools ahead of it, as described above. It seems probable, therefore, that the geologic time actually involved in the accumulation of any given oil or gas pool was relatively short, and when once formed the pool became a firmly fixed, very permanent part of the rock mass and since has suffered little or no change either in its stratigraphic or geographic position.

The principal object of this paper, however, is not to discuss the theories of oil and gas accumulation, but to show the local structure of the Grandfield district, and to emphasize the fact that, regardless of the various modifying factors of accumulation in a given area, the location of the larger percentage of pools is influenced more or less by the structure, and that a detailed knowledge of the structure in a given area is often sufficient to enable a company to greatly increase its chances of finding oil or gas, and that a lack of this information often leads to the drilling of holes in unfavorable territory. This fact is illustrated by the four wells drilled in the Grandfield district. The George Cabella well No. 1 (No. 12 of the well-section sheet, Pl. III), in the NW. ¼ sec. 28, T. 3 S., R. 13 W., is almost exactly in the trough of a small syncline adjacent to the Deep Red syncline. The "Big Pasture well" at Loveland, in T. 3 S., R. 15 W., is also near the bottom of this trough at a very unfavorable location. The shallow well in the SE. ¼ sec. 30, T. 4 S., R. 11 W., seems to be some distance south of the axis of the Devol anticline, but is still very favorably located for oil or gas. However, the chances of getting oil or gas in this well could have been materially increased if it had been located a mile to the northwest. But, as is shown on Plate III (well-section sheet), these wells very probably were not drilled deep enough to be regarded as tests, and the time and money spent upon them were wasted.

The fourth well, drilling at this date (July, 1913) at Grandfield, is located in a fairly favorable place on the south limb of a small dome, but the chances of finding oil or gas in this vicinity would have been slightly increased by locating it half a mile northwest of the point selected. The domes shown by the contours on Plate IV should be tested first in this district. The higher the domes the better. If first wells so located furnish gas in commercial quantities in any sand, they will show that the general conditions in the area were favorable for its accumulation and that the same sand at a lower level on the anticline is very likely to contain good pools of oil. If, however, the domes prove to contain no oil or gas and carry salt water under considerable head in the various sands down to 3,000 feet, the prospect of finding gas or oil in the district as a whole is

unfavorable. If, on the other hand, the higher domes carry no salt water, oil, or gas in any sand, the lower domes and secondary anticlines should be tested, especially those nearest the Burkburnett field. The fact that these beds carry oil in the Burkburnett field suggests that the lower domes and secondary anticlines in the eastern part of the district bring the oil sands up to about the right elevation for accumulations, in which case the higher domes to the west may carry gas almost exclusively. At all times it must be remembered that the three favorable factors to get in combination are (1) an anticline, (2) a good open sand, and (3) the right height on the anticline with reference to salt water in the porous sand. It is evident that in wildcat tests only one of these factors—structure—can be determined in advance of the drill, but, having it given, the chances are at least increased one-third. Once the combination of all three is found the test for an oil or gas pool, whether successful or not, is at least complete for that vicinity.

[illegible]

INDEX.

A.

	Page.
Accumulation of oil and gas, theories of	77-82
Acknowledgments	6
Anticlines, minor, form and position of	33-34
Auger conglomerate lentil, character of	23
sections containing	23-26
Auger Creek, exposures on	42, 43

B.

Big Blue Creek, exposures on	48-49
Breaks, nature and importance of	7

C.

Cache Creek, exposures on or near	71
Curtis Creek, exposures on	44, 46

D.

Deep Red Run, exposures on or near	50-51, 51-55, 55-58, 59-62, 68-70, 70-71
features of	7
Deep Red syncline, form and position of	32-33
Devol anticline, form and position of	31-32
Dimetrodon, occurrence of	39
Drainage of the district	6-7

F.

Field work	5-6

G.

Gordon, C. H., cited	8
Grandfield conglomerate, character and occurrence of	17, 28-30

H.

Halsell well No. 1, log of	12-15
Historical geology, items of	9

L.

Little Blue Creek, exposures on or near	42, 47, 49
Location of the district	5

M.

Middle Fork of Deep Red Run, exposures near	38
Montgomery, J. F., acknowledgments to	6

N.

Newby, Jerry B., work of	5

O.

Obern, D. W., acknowledgments to	6
Oil and gas, theories of accumulation of	77-82
Oklahoma Geological Survey, cooperation by	5

P.

	Page.
Pennsylvanian rocks, occurrence of	8-17
Permian rocks, occurrence of	7-8, 18-28
Phillips, D. McN. *See* Udden, J. A.	
Prospectors, suggestions to	74-83

Q.

Quaternary deposits, character and occurrence of	30-31

R.

"Red Beds," occurrence of	7, 8, 9, 17
Red River, exposures on	35, 45, 63-65, 73
features of	6-7

S.

Settler Creek, exposures near	36
Slough Creek, exposures on or near	65-67
Slough Fork of Deep Red Run, exposures near	38-40
Stratigraphy, general features of	7-31
Structures, general features of	31-34
Synclines, local, form and position of	34

T.

T. 3 S., R. 12 W., rocks exposed in	70-71
T. 3 S., R. 13 W., rocks exposed in	55-59
T. 3 S., R. 14 W., rocks exposed in	51-55
T. 3 S., R. 15 W., rocks exposed in	37-41
T. 3 S., R. 16 W., rocks exposed in	37
T. 4 S., R. 11 W., rocks exposed in	71-73
T. 4 S., R. 12 W., rocks exposed in	68-70
T. 4 S., R. 13 W., rocks exposed in	59-63
T. 4 S., R. 14 W., rocks exposed in	46-51
T. 4 S., R. 15 W., rocks exposed in	41-45
T. 4 S., R. 16 W., rocks exposed in	35-37
T. 5 S., R. 11 W., rocks exposed in	73-74
T. 5 S., R. 12 W., rocks exposed in	65-68
T. 5 S., R. 13 W., rocks exposed in	63-64
T. 5 S., R. 14 W., location of	45
T. 5 S., R. 15 W., rocks exposed in	45
T. 5 S., R. 16 W., rocks exposed in	34-35
Taff, J. A., cited	10
Test wells, favorable places for	74-83
Topography of the district	6-7

U.

Udden, J. A., and Phillips, D. McN., cited	12-15, 16-17, 18, 29

W.

Wells, locations of	82
Wichita formation, character and occurrence of	18-22

[illegible]

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 548

ELECTRIC ACTIVITY IN ORE DEPOSITS

BY

ROGER C. WELLS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

CONTENTS.

	Page.
Preface, by George Otis Smith	5
Introduction	7
General discussion of the phenomena	9
Effect of various solutions on the potentials shown by minerals	9
Availability of the combinations to furnish current	12
Electric currents in the earth	19
Effect of a current from solution to mineral	21
Method of experiment	21
Effects at the cathode with moderate currents	21
Effects at the cathode with feeble currents	22
Effect of a current from mineral to solution	23
Electric conductivity of minerals	24
Detailed study of various potentials	26
General results of the measurements	26
Measurements of potential assumed by certain minerals	30
Pyrolusite	30
Pyrite	32
Marcasite	39
Pyrrhotite	41
Magnetite	41
Galena	42
Silver sulphide	44
Bismuth sulphide	44
Mercuric sulphide	45
Nickel and other sulphides	45
Electromotive behavior of soluble sulphides	45
Reducing power of soluble sulphides	45
Relation between potential and concentration	47
Preparation of sodium hydrosulphide	48
Chemistry of the sulphide electrode	49
Behavior of polysulphides	51
Effect of dilution	51
Conclusions	54
Correlation of the measurements of potential	54
Application to ore deposition	62
General conditions	62
Deposition of ores	64
Solution of ores	69
Summary	72
Index	75

ILLUSTRATIONS.

		Page.
FIGURE 1.	Apparatus for studying currents produced by combinations of solutions and minerals	13
2.	Method of supplying fresh solution to mineral electrodes without affording access of air	27
3.	Half cell of mineral suspended in a solution for observation over a long period	29
4.	Apparatus for boiling out air under reduced pressure before measuring electromotive force	35
5.	Curves showing rate of polarization	37
6.	Mounting of pyrite to obtain a saturated solution over a long period without access of air	38
7.	Single potentials of oxygen and hydrogen electrodes in water	58

PREFACE.

By George Otis Smith.

Until the last few years the contributions to the study of ore deposits by members of the United States Geological Survey have been primarily geologic. Close observation of the facts of geologic occurrence and mineral association has been the rule, less attention having been given to the chemical and physical questions involved in problems of ore deposition. Notable exceptions have been studies by G. F. Becker and Carl Barus [1] of electric activity in the Comstock lode and the lodes of Eureka, Nev., the chemical investigation by Becker and Melville of solution and precipitation of metallic sulphides,[2] studies by C. R. Van Hise and C. K. Leith [3] of the chemistry of iron-ore deposition, and the work of Waldemar Lindgren [4] on the relations between ore deposition and physical conditions. Recently, however, unusual interest has been awakened in the geochemical and geophysical phases of the problem. This interest has manifested itself in such work as that of Victor Lehner,[5] of the University of Wisconsin, and A. D. Brokaw,[6] of the University of Chicago, on the solution and deposition of gold, and in studies begun by L. C. Graton, of Harvard University, and his associates, of the enrichment of copper ores.

Among the contributions already made by the United States Geological Survey are the published results of studies by W. H. Emmons[7] of the general subject of enrichment, and of investigations now being carried on by E. S. Bastin [8] and Chase Palmer of the enrichment of silver ores as exemplified in our western mining camps. The work reported in the present paper on electric activity in ore deposits elaborates and extends the work of Gottschalk and Buehler.[9]

[1] Geology of the Comstock lode and the Washoe district: U. S. Geol. Survey Mon. 3, pp. 309-367, 1882.

[2] Geology of the quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, chap. 15, 1888.

[3] Summarized in U. S. Geol. Survey Mon. 52, pp. 518-545, 1911.

[4] Ore deposition and deep mining: Econ. Geology, vol. 1, pp. 34-46, 1905; The relation of ore deposition to physical conditions: Idem, vol. 2, pp. 105-127, 1907.

[5] The transportation and deposition of gold in nature: Econ. Geology, vol. 7, pp. 744-750, 1912.

[6] The secondary precipitation of gold in ore bodies: Jour. Geology, vol. 21, pp. 251-267, 1913.

[7] The enrichment of sulphide ores: U. S. Geol. Survey Bull. 529, 1913.

[8] Metasomatism in downward sulphide enrichment: Econ. Geology, vol. 8, pp. 51-63, 1913; Metallic minerals as precipitants of silver and gold: Idem, pp. 140-170, 1913.

[9] Econ. Geology, vol. 5, pp. 28-35, 1910; vol. 7, pp. 15-34, 1912.

It is interesting to note that this bulletin by Mr. Wells relates to a subject mentioned by Becker[1] in his first administrative report to Director King as deserving study, a suggestion that was followed by the investigation by Barus. The electromotive forces detected in the present detailed quantitative laboratory studies of the activity of various metalliferous minerals in various solutions show few intensities as great as one volt, though some of them are many times greater than the largest electromotive forces actually found in ore deposits by the earlier observers. Moreover, the effects of difference in solutions are found to be greater than those due to mineralogic differences.

It should be emphasized that the results thus far obtained afford no adequate basis for any method of electric prospecting nor any promise of the development of such a method by connecting the presence of ore deposits with readily or definitely measurable electric activity. Nevertheless, the data here presented are believed to possess value in the broader investigation of ores, for even feeble currents might exert a directional influence on ore deposition, and chemical conditions, even at a distance, might be a factor in determining mineral association.

---

[1] U. S. Geol. Survey First Ann. Rept., p. 46, 1880.

ELECTRIC ACTIVITY IN ORE DEPOSITS.

By Roger C. Wells.

INTRODUCTION.

As long ago as 1830 R. W. Fox called attention to electric activity in ore deposits.[1] Such currents as he was able to detect seemed to have no relation to the points of the compass, but appeared to be due to connections existing between different bodies of ore, or between different parts of the same body. In one mine the ore appeared to be increasingly negative with depth, a fact which he suggested might be dependent on temperature. His original paper contained a table showing the order of the electric conductivity of about twenty minerals and mineral combinations. In a later paper[2] he took pains to show that certain ores may act like metals in galvanic combinations, and his principal conclusions are summed up in the statement that the electric phenomena in veins "bear a striking resemblance to galvanic combinations." From 1830 to 1844 discussion of these points was carried on by Henwood[3] and Fox[4] in England and by Von Strombeck[5] and Reich[6] in Germany without important advances.

The subject was considered from a somewhat different point of view in 1870 by W. Skey.[7] Whereas the preceding investigators had sought for currents over large areas, Skey confined his observations to laboratory experiments on single minerals. He enlarged the known list of conducting minerals and determined the direction of

---

[1] Fox, R. W., On the electromagnetic properties of metalliferous veins in the mines of Cornwall: Philos. Trans., 1830, pt. 2, p. 399.

[2] Fox, R. W., Note on the electric relations of certain metals and metalliferous minerals: Philos. Trans., 1835, pt. 1, p. 39.

[3] Henwood, W. J., Sur les courants électriques observés dans les filons de Cornouailles: Annales des mines, 3d ser., vol. 11, p. 585, 1837.

[4] Fox, R. W., Account of some experiments on the electricity of the Huel Jewel mine: British Assoc. Adv. Sci. Rept., vol. 3, p. 572, 1834; Report on some experiments on the electricity of metallic veins, etc.: Idem, vol. 6, p. 133, 1837; Some experiments on subterranean electricity, made at Pennance mine, near Falmouth: Philos. Mag., 3d ser., vol. 23, pp. 457, 491, 1843.

[5] Strombeck, A. von, Ueber die von Herrn Fox angestellten Untersuchungen in Bezug auf die elektromagnetischen Aeusserungen der Metallgänge: Karsten's Archiv, vol. 6, p. 431, 1833.

[6] Reich, F., Notiz über elektrische Ströme auf Erzgängen: Poggendorff's Annalen, vol. 48, p. 287, 1839; Versuche über die Aufsuchung von Erzen mittelst des Schweiger'schen Multiplicators: Berg- und hüttenmänn'sche Zeitung, vol 3, pp. 342, 356, 1844.

[7] Skey, W., On the electromotive power of metallic sulphides: New Zealand Inst. Trans. and Proc., vol. 3, pp. 232-236, 1871.

the current when conducting minerals in contact with solutions are connected by a wire. Besides pointing out anew that conducting minerals are capable of forming the electrodes of galvanic batteries he called attention to the accelerating or retarding action of one mineral on another in chemical changes—action due to electric activity.

In 1880, at the instance of G. F. Becker, Carl Barus[1] investigated the electric activity of the Comstock lode and of the ore deposits at Eureka, Nev. Although he followed the experimental methods of Fox, Barus appears to have purposely avoided contact with metalliferous minerals. He concluded, from the measurements made at the Comstock lode[2] "that the electromotive forces due purely to chemical difference and polarization of the terminals are of the same order as the data expressing the electric activity of the lode." At Eureka the potentials of 21 points were measured against a single point of reference with terminals particularly designed to make a good contact with the solutions in the rocks. The maximum potential above the point of reference was 0.018 volt and the maximum below 0.093 volt. In the words of Barus:[3] "On reviewing the results described it is strikingly evident that the electromotive forces met with are invariably small, very frequently, indeed, quite at the limit of the accurately measurable." Electric prospecting, therefore, appeared to Barus impracticable, but he adds:[4]

> It will be desirable to carry out Fox's original idea, namely, of investigating the electrical properties of ores and minerals of the heavy metals * * *. The knowledge we possess of the conductivity and the position of ores in the electrical scale is largely the result of experiments made a long time ago. Recent observers have made but few quantitative additions, and even these—probably from improperly chosen methods—are frequently discordant.

In 1891 Braun[5] clearly proved that certain phenomena attending the formation of sulphides and the deposition of copper in capillary spaces, previously noted by A. C. Becquerel, are of an electrochemical nature, as Becquerel had in fact suggested.[6] These phenomena are partly dependent, according to Ostwald,[7] on the semipermeability of precipitated membranes. It is not possible in this paper, however, to discuss the complications that would be introduced into the question by so extending it as to consider capillary spaces and semipermeable membranes.

---

[1] Becker, G. F., Geology of the Comstock lode and the Washoe district: U. S. Geol. Survey Mon. 3, pp. 309–367 (chap. 10, On the electrical activity of ore bodies, by Carl Barus), 1882.

[2] Idem, p. 322.

[3] Idem, p. 365.

[4] Idem, p. 366.

[5] Braun, F., Electrocapillare Reactionen: Annalen der Physik und Chemie, vol. 44, p. 507, 1891.

[6] Becquerel, A. C., Sur des nouveaux effets chimiques produits dans les actions capillaires: Compt. rend., vol. 64, pp. 919–924, 1867; vol. 65, pp. 51–60, 720–729, 1867; vol. 66, pp. 77–81, 245–247, 766–924, 1066–1072, 1868; particularly vol. 65, p. 51, 1868.

[7] Ostwald, W., Elektrische Eigenschaften halbdurchlässiger Scheidewände: Zeitschr. physikal. Chemie, vol. 6, p. 75, 1890.

Experiments along the line indicated by Barus were made in 1897 by Bernfeld,[1] who studied the electric behavior of galena particularly, and more recently by Gottschalk and Buehler, who had previously shown that the oxidation and solution of certain natural sulphides are accelerated under certain conditions by the presence of pyrite or marcasite.[2] In explanation of this action E. T. Allen[3] and I[4] separately ventured to express the opinion that it might be due to the production of sulphuric acid by the pyrite and marcasite. Soon afterward, in another paper, Gottschalk and Buehler pointed out once more that there may be electric action between different sulphides in contact; further, that marcasite and pyrite, which are electrically positive to stibnite and sphalerite when in moist contact with them, are in fact themselves somewhat protected from oxidation by the complementary action of the more oxidizable sulphides. They accordingly ascribed the chemical effects observed by them partly to electric action, and presented a list of conducting minerals and a table giving the electromotive forces shown by several minerals with respect to copper, water serving as electrolyte.

This explanation of the alteration of ores by electrolysis is similar to the electrolytic theory of the corrosion of iron and steel and of the zinc of zinc plate. In view of the importance of the subject it has seemed desirable to extend the data, not only to correlate field results with laboratory experiments, but also to elucidate the effect of various solutions on the potentials and to harmonize the whole subject with modern theories, such as those of electricity and solution. The data presented in this bulletin greatly enlarge the scope of possible investigation. It is well realized that more detailed experimental work is both desirable and necessary, but it has seemed best to set forth at this time what has already been done.

GENERAL DISCUSSION OF THE PHENOMENA.

EFFECT OF VARIOUS SOLUTIONS ON THE POTENTIALS SHOWN BY MINERALS.

The potentials of different minerals as presented by Gottschalk and Buehler were determined by using water as the electrolyte and metallic copper as the second electrode.[5] Their opinion was that the electrolytic action of the sulphides "would be analogous in every respect to the action of metals." But although it is well known that the potential shown by a metal as electrode depends on the concentration of the metallic ion in the solution in contact with it, Gottschalk and Buehler presented no data on the effect of variation in the solution.

---

[1] Bernfeld, I., Studien über Schwefelmetallelektroden: Zeitschr. physikal. Chemie, vol. 25, p. 46, 1898.

[2] Buehler, H. A., and Gottschalk, V. H., Oxidation of sulphides: Econ. Geology, vol. 5, p. 28, 1910.

[3] Econ. Geology, vol. 5, p. 387, 1910.

[4] Idem, p. 480.

[5] Gottschalk, V. H., and Buehler, H. A., Econ. Geology, vol. 7, p. 31, 1912.

This was therefore the first subject to be investigated. A few measurements soon showed that not only do different minerals employed as electrodes exhibit different potentials in a given solution but also that the potentials shown by most minerals, certainly the initial values, depend to a marked degree on the nature of the solutions in contact with the minerals. The variation shown by a mineral in passing from an acid to an alkaline solution is in fact generally greater than the differences shown by diverse minerals in the same solution. The potentials also depend on the oxidizing or reducing nature of the solutions. In general, acid and oxidizing solutions give the highest potentials, alkaline and reducing solutions the lowest.

A most significant fact for the elucidation of these phenomena is that any unattackable electrode, such as a piece of smooth platinum, shows somewhat similar behavior in the various solutions. The table below gives a few single potential measurements which illustrate this point. The solutions were approximately normal and the sign is that assumed by the electrode with reference to the normal calomel electrode as +0.560 volt, the measurements being made soon after the specimens were placed in the solutions. Of course neither equilibrium nor constancy was wholly obtained under these circumstances in the time allowed.

Effect of various solutions on the potential, in volts.

	Pyrite.	Galena.	Magnetite.	Pyrrhotite.	Platinum.
Acidified ferric sulphate	+1.10	+0.80	+0.91	+0.97	+1.11
Sulphuric acid	+ .86	[a]+ .49	+ .88	+ .89	+ .97
Potassium chloride	+ .72	+ .49	+ .68	+ .56	+ .76
Sodium hydroxide	+ .38	[a]+ .16	+ .53	[a]+ .13	+ .38
Sodium sulphide	− .17	− .22	− .14	[a]− .14	− .26

[a] Mineral appreciably attacked, yielding an indefinite value.

On considering these results a number of important questions at once arise. Is it possible to frame a consistent explanation of all the values? How constant and reproducible are they? Which of them, if any, are capable of furnishing noteworthy currents for electrolytic action? Is such action possible in ore deposits? If so, what are the effects of electrolytic action on various minerals? I shall attempt to give answers to these questions by discussing known facts as well as by presenting new experimental evidence on the subject.

It may be said at once that most of these potentials are reproducible to tenths of a volt and some to hundredths. Our knowledge of the behavior of various electrodes would lead us to expect, however, that the products formed by solution of the minerals would have an effect on the potentials. To yield significant potentials the solutions

should contain definite concentrations of the possible reacting substances, but as the concentrations could not be regulated by the method of experimentation used above the values are simply illustrative and have no exact quantitative significance.

The measurements are suggestive, however, because they represent temporary stages in slow chemical adjustments. Some of these adjustments occur very slowly, so slowly that fairly constant potentials are soon obtained; others occur more rapidly and the reaction products cause a changing potential. Measurements of electromotive force may be used to indicate the direction and intensity of a given chemical action and generally furnish such indications with as great accuracy as chemical experimentation. Moreover, such measurements may be made quickly.

The potentials shown by the minerals and the platinum as indicated in the preceding table evidently have something in common and are affected in a similar way by the nature of the solutions. The variations shown seem to be characteristic of the potentials ordinarily termed "oxidation and reduction" potentials. When the electrode appears positive the usual assumption is that positive electricity has passed from some ion in the solution to the conductor (platinum ordinarily), or, what amounts to the same thing, that negative electricity has passed from the electrode to the solution. The ferric ions present in a ferric salt solution, for example, are capable of acting as oxidizers—that is, of parting with a portion of their electrification and thereby becoming converted into ferrous ions. The electric potential measures the tendency of this chemical process to occur. Evidently this general effect is shown even with the mineral electrodes in the above measurements, but with the minerals there is the added possibility that their constituents may ionize and carry electric charges with them into the solution as they dissolve. Considering the similar effects shown by the minerals and by platinum, however, it must be said that the potentials indicate in a general way the order of the oxidizing power of the solutions.

For further measurements of such potentials one may refer to the experiments made by Bancroft on a large number of oxidizing and reducing solutions.[1] In 1898 R. Peters showed that the value of the ferric-ferrous potential is dependent on the concentrations of both ferric and ferrous salt, and succeeding investigators have found that such potentials are much more definite when the salts of both valencies are present in about equal amounts. The present custom is to take as the normal oxidation and reduction potential the value shown when the two ions concerned, if these can be determined, are present

[1] Bancroft, W. D., Ueber Oxydationsketten: Zeitschr. physikal. Chemie, vol. 10, p. 387, 1892.

in equal concentration. The single ferric-ferrous potential, for example, can be represented by the following equation:[1]

$$E = 1.016 + 0.059 \log \frac{[Fe^{+++}]}{[Fe^{++}]}$$

in which E is the potential in volts and the bracketed symbols stand for concentrations of the respective ions. It can be seen that at equal concentrations of ferric and ferrous ions the second term vanishes. The value 1.016, then, represents the single potential of the ferric-ferrous electrode provided the normal calomel electrode has a potential of 0.560 volt. The electromotive behavior of substances possessing several stages of oxidation has been very fully studied and discussed by R. Luther.[2]

There can be no question, then, that the potentials shown by unattackable electrodes are related to the oxidizing or reducing nature of the solutions in contact with them, and further, that a number of the common metalliferous minerals exhibit initial potential values which may obviously be referred to the same cause.

These facts may possibly help us to explain in part the electromotive forces noted in the earth by Fox. The solutions in the upper levels of ore deposits are likely to be oxidizing and acid, but with increase in depth they become more reducing and less acid. For these reasons isolated portions of ore in the upper levels may possess a higher electric potential than portions in the lower levels, and such detectable electric currents as might be caused by this difference would be more likely to take a vertical than a horizontal direction. Of course variations in the nature of the solutions might also give rise to differences in potential in horizontal directions. However, the presence of dissimilar solutions in contact with ores suggests a very probable cause of differences of potential in the earth.

AVAILABILITY OF THE COMBINATIONS TO FURNISH CURRENT.

It appeared to be a matter of practical importance to determine whether the above potentials could yield currents available for producing appreciable chemical action or whether such electrodes are very easily polarizable. This question was accordingly put to an experimental test.

There seems to be no question about the competency of an oxidizing solution like acidified ferric sulphate to furnish a noteworthy current when a platinum electrode is employed as a cathode and conjoined with any unpolarizable anode. In order to compare this action with that occurring when electrodes of pyrite are involved

[1] See Noyes, A. A., and Brann, B. F., The equilibrium of the reaction between metallic silver and ferric nitrate: Am. Chem. Soc. Jour., vol. 34, p. 1025, 1912.

[2] *Luther, R., Zeitschr.* physikal. Chemie, vol. 34, p. 488, 1900; vol. 36, p. 385, 1901.

the following experiments were performed: In one beaker was placed an acidified solution of ferric sulphate, in another beaker a solution of sodium sulphide (see fig. 1), both solutions being approximately normal. The platinum electrodes measured 2 by 2 centimeters. The beakers were connected by a wick saturated with normal sodium sulphate. (See fig. 1.) The potential of this combination on open circuit, calculated by the data in the table on page 10, is 0.93 volt. The external circuit was completed by a voltmeter and sufficient additional resistance was introduced to bring the total resistance of the circuit, including the resistance of the liquid (all resistances being actually determined), up to 3,000 ohms, which is comparable to the resistance of some geologic strata. On closing the circuit the electromotive forces and currents tabulated below were noted, the electromotive force stated being equivalent to the fall in potential over the whole circuit.

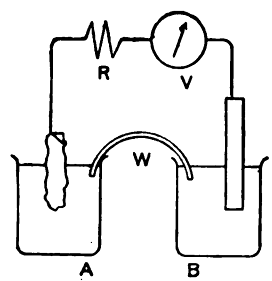


FIGURE 1.—Apparatus for studying currents produced by combinations of solutions and minerals. A, B, beakers containing solutions; R, resistance; V, voltmeter; W, wick or tube.

Oxidation and reduction current with platinum electrodes.

Time.	Effective electromotive force.	Current.
	Volt.	*Milliampere.*
0.1 minute	0.96	0.31
1 minute	.94	.30
5 minutes	.94	.30
10 minutes	.88	.29
16 hours	.76	.25

The current was found to vary, of course, with the resistance of the circuit. As it continued to flow reduction ensued at the cathode and oxidation at the anode, thereby equalizing the differences and slowly lowering the potential and current. It was not thought necessary to extend the readings further, as the availability of the combination to furnish a noteworthy current was shown. Electrodes of pyrite were then substituted for the platinum. The external resistances were lowered to bring down the total again to 3,000 ohms, when the following results were noted:

Oxidation and reduction current with electrodes of pyrite.

Time.	Effective electromotive force.	Current.
Minutes.	*Volts.*	*Milliampere.*
0.1	1.04	0.34
1.0	1.02	.33
5.0	1.00	.33
10.0	1.00	.33

It is evident from these results that chemical differences between solutions are capable of producing appreciable currents for some time whether the electrodes are of platinum or of a conducting mineral. The polarization appeared to be a little greater, in fact, with the platinum than with the pyrite. The important point for geologic application is that the chemical differences may be equalized at considerable distances as well as locally by electrolytic action when the proper circuits are present. For the elucidation of other similar combinations of solutions and minerals the following additional experiments were performed, all the solutions being approximately normal:

Currents produced in a circuit of 3,000 ohms resistance by different solutions.

Combination.	Minutes.	Volt.	Milli-ampere.
Platinum / potassium chlorate / sodium sulphide / platinum	0.1 1.0 5.0 10.0	0.51 .39 .31 .25	0.17 .13 .10 .08
Pyrite / potassium chlorate / sodium sulphide / pyrite	.1 1.0 5.0 10.0	.71 .61 .47 .41	.23 .19 .15 .13
Platinum / acid ferric sulphate / ferrous sulphate / platinum	.1 1.0 5.0 10.0	.22 .21 .21 .21	.08 .07 .07 .07
Pyrite / acid ferric sulphate / ferrous sulphate / pyrite	.1 1.0 5.0 10.0	.17 .15 .14 .14	.06 .05 .05 .05
Platinum / potassium chloride / sodium sulphide / platinum	.1 1.0 5.0 10.0	.24 .21 .19 .17	.10 .08 .07 .06
Pyrite / potassium chloride / sodium sulphide / pyrite	.1 1.0 5.0 10.0	.45 .38 .28 .25	.16 .13 .10 .08
Platinum / sulphuric acid / sodium hydroxide / platinum	.1 1.0	.02 ([a])	.007 ([a])
Pyrite / sulphuric acid / sodium hydroxide / pyrite	.1 1.0 5.0 10.0	.40 .08 .06 .04	.13 .03 .02 .01
Galena / sulphuric acid / sodium hydroxide / galena	1.0 10.0	.06 .05	.019 .016

[a] Negligible.

As the same conductors were used on each side of the above combinations the currents developed must be ascribed to the effect of the solutions. It will be seen, however, that only those solutions which are ordinarily thought to be capable of fairly easy oxidation or reduction furnish noteworthy currents with platinum electrodes. Most other solutions quickly polarize the platinum, leaving only very small

"residual currents" flowing. Such "residual currents" are ordinarily considered to be due to the fact that the polarizing substances slowly diffuse away from the electrodes while the supply is renewed by the current. With the mineral electrodes the polarization is a little less evident, so that appreciable currents are produced for some time, and with solutions that are also capable of oxidation and reduction the currents may equal or even exceed those produced with platinum electrodes.

In contrast to the preceding results obtained by using different solutions it was found that the currents yielded by different minerals in the same solution are much smaller, being more of the order of "residual currents." In the following experiments the circuit was similar to that above, except that the wick was not used and that the two minerals were dipped into the same solution:

Currents produced by different minerals in the same solution.

Combination.	Minutes.	Volt.	Milli-ampere.
Marcasite / potassium chloride / galena	0.1	0.20	0.07
	1.0	.10	.03
	5.0	.06	.02
	10.0	.06	.02
Marcasite / potassium chloride / pyrrhotite	.1	.18	.08
	1.0	.09	.04
	5.0	.03	.013
Pyrite / sodium hydroxide / chalcocite	1.0	.04	.013
	5.0	<.02	<.01
Pyrite / sodium hydroxide / magnetite	1.0	<.02	<.01
Pyrite / potassium chloride / magnetite	1.0	<.02	<.01
Pyrite / cupric sulphate / galena	1.0	<.02	<.01
Pyrite / potassium chloride / pyrrhotite	1.0	<.02	<.01

Evidently polarization here put a stop to the action in a moment or so, although the potentials on open circuit, as shown on page 10, might have led one to expect appreciable currents.

In order to proceed further in the elucidation of these phenomena it appeared desirable to reduce the number of variables by considering each electrode separately. It follows from the first results that if a solution is easily oxidizable or reducible no electrode will be quickly polarized. It is also well known that the base metals dissolve as anodes with very little polarization. It therefore seemed the simplest way to set up cells with the various minerals as cathodes and a piece of zinc or copper as anode and record the polarization at the cathode with a given solution. In this way every difference but that of the mineral alone was eliminated. The results in potassium chloride follow.

Polarization at the cathode.

Combination.	Minutes.	Volt.	Milli-ampere.
Pyrolusite / potassium chloride / zinc	0.1	1.31	0.45
	1.0	1.29	.44
	10.0	1.17	.40
Chalcocite / potassium chloride / zinc	.1	.82	.37
	1.0	.80	.37
	10.0	.82	.37
Pyrrhotite / potassium chloride / zinc	.1	.83	.27
	1.0	.73	.24
	10.0	.69	.23
Marcasite / potassium chloride / zinc	.1	.78	.26
	1.0	.68	.23
	10.0	.60	.20
Pyrite / potassium chloride / zinc	.1	.76	.25
	1.0	.64	.21
	10.0	.62	.21
Galena / potassium chloride / zinc	.1	.61	.21
	1.0	.55	.19
	10.0	.48	.16
Covellite / potassium chloride / zinc	.1	.43	.14
	1.0	.43	.14
	10.0	.43	.14
Platinum / potassium chloride / zinc	.1	.45	.15
	1.0	.35	.12
	10.0	.35	.12

The minerals have been arranged in the order of increasing polarizability as cathodes. This polarization doubtless depends partly on the solubility of the mineral and possibly also on the rate of solution or diffusion, but whatever may be its cause the experiments indicate an effective difference in action between different minerals. The same intensity was striving to evolve potassium (or hydrogen) in every experiment, but the minerals show different abilities to combine with or remove the hydrogen. The order is roughly that of the effective oxidizing power of the minerals. If the currents had been smaller, the polarization would have been less until, with the limiting condition of no current, the potential would represent exactly the oxidizing intensity of the cathode system. The limiting values would have theoretical rather than practical value, however, because they would contain no expression of the efficiency or the rate of the action, which is significant for geologic application. Moreover, there are various difficulties in determining the limiting values, among which are the facts that exceedingly small concentrations of certain ions determine the results obtained, that these small concentrations are not reproducible without rigorous exclusion of air, and finally that the minerals themselves often contain impurities. These points will be more fully considered under the headings covering the separate minerals.

The same minerals were polarized by a smaller current—that obtained with copper. The results follow.

Polarization at the cathode with a copper anode.

Combination.	Minutes.	Volt	Milli-ampere
Pyrolusite / potassium chloride / copper	0.1	0.29	0.10
	1.0	.29	.10
	10.0	.25	.08
Chalcocite / potassium chloride / copper	.1	.21	.07
	1.0	.17	.03
	10.0	.08	.03
Marcasite / potassium chloride / copper	.1	.29	.10
	1.0	.08	.03
	10.0	.06	.02
Pyrrhotite / potassium chloride / copper	.1	.12	.04
	1.0	.08	.03
	10.0	.06	.02
Covellite / potassium chloride / copper	.1	.24	.08
	1.0	.08	.03
	10.0	.02	.01
Pyrite / potassium chloride / copper	10.0	.04	.01
Galena / potassium chloride / copper	1.0	(a)	(a)
Platinum / potassium chloride / copper	1.0	.04	.01
	5.0	(a)	(a)

a Negligible.

The order of polarizability here shown is about the same as before. Pyrolusite is evidently the least polarizable cathode in potassium chloride solution.

Now using pyrolusite as a cathode, other minerals were studied as anodes, with the following results:

Polarization at the anode in potassium chloride solution.

Combination.	Minutes.	Volt	Milli-ampere
Pyrolusite / potassium chloride / chalcopyrite	0.1	0.14	0.03
	1.0	.05	.02
	5.0	.02	.01
Pyrolusite / potassium chloride / covellite	.1	.12	.04
	1.0	.02	.01
	5.0	.02	.01
Pyrolusite / potassium chloride / pyrite	.1	.05	.02
	1.0	.02	.01
Pyrolusite / potassium chloride / magnetite	.1	.16	.05
	1.0	.04	.012
Pyrolusite / potassium chloride / gold	.1	.06	.015
	1.0	.02	.01

Most of these combinations did not yield sufficient electromotive force to show differences in polarization at the anode. The experiments were therefore repeated with a cathode of slightly higher electromotive force, namely, pyrite and ferric sulphate. This was connected to the beaker of potassium chloride by means of a wick,

the total resistance being 3,000 ohms, as in all these experiments. Each cell was of the form—

Pyrite / acid ferric sulphate / potassium chloride / mineral.

The results are tabulated below in the order of increasing polarizability, only the anodes being stated:

Polarization at the anode.

Anode.	Minutes.	Volt.	Milliampere.
Potassium chloride / iron	0.1 1.0 10.0	0.92 .92 .92	0.31 .31 .31
Potassium chloride / copper	.1 1.0 10.0	.60 .60 .60	.20 .20 .20
Potassium chloride / silver	.1 1.0 10.0	.39 .39 .39	.13 .13 .13
Potassium chloride / chalcocite	.1 1.0 10.0	.39 .35 .35	.13 .12 .12
Potassium chloride / galena	.1 1.0 10.0	.39 .33 .25	.13 .11 .08
Potassium chloride / pyrrhotite	.1 1.0 10.0	.33 .25 .16	.11 .08 .05
Potassium chloride / covellite	.1 1.0 10.0	.25 .24 .22	.08 .08 .07
Potassium chloride / marcasite	.1 1.0 10.0	.23 .08 .03	.08 .03 <.01
Potassium chloride / chalcopyrite	.1 1.0 10.0	.21 .19 .16	.07 .06 .05
Potassium chloride / pyrite	.1 1.0 10.0	.19 .14 .06	.06 .04 .02
Potassium chloride / magnetite	.1 1.0 10.0	.19 .08 .03	.06 .03 <.01
Potassium chloride / gold	....	(a)	(a)

a Negligible.

Here, one may say, the same electromotive force was striving to deposit oxygen on the anode. The order in which the minerals are arranged in the table is therefore the order of their effective reducing power (or of their oxidizability) under the conditions of the experiment. The results show a wide range of polarization. That currents smaller than 0.01 milliampere may be generated for long periods by the less favorable combinations has been proved by several tests. As a current of 0.01 milliampere could deposit 1 milligram of silver a day, it can be seen that even currents so small have geologic significance and that larger currents may produce noteworthy chemical effects.

But the chief object of the above experiments was to establish the magnitude of the currents actually produced by various combinations as compared with that of currents generated by ordinary galvanic cells. On viewing the results as a whole it is evident that different minerals in the same solution are much less efficient than combinations containing oxidizing and reducing solutions. This difference may probably be ascribed to the fact that the differences in concentration produced by the solution of different minerals are necessarily small, whereas with more soluble salts the concentrations of the effective ions are enormously greater.

ELECTRIC CURRENTS IN THE EARTH.

In the earth the two electrodes and wire of figure 1 might have their counterpart in a single portion of ore or several ores in contact. The liquid connection might consist of moist rocks or vein solutions. Many possible combinations in the earth's crust might produce electric action. By a judicious use of the imagination it is possible to perceive that this action might affect either fairly large zones or, on the other hand, might contribute to the development and alteration of the most minute particles in tiny veinlets.

In the preliminary measurements of the potential shown by various minerals in various solutions, tabulated and discussed at the beginning of this paper, it was recorded that some of the minerals were appreciably attacked. It may now be stated that there are good reasons to believe that all minerals are attacked by all solutions, but in widely varying degrees. For example, even pyrite, one of the least attackable sulphides, is affected slowly by acidified ferric sulphate. The action results in the production of ferrous salt in the solution, which may proceed both from the reduction of the ferric salt and from the solution of a part of the iron of the pyrite. Experiments have shown that a dilute acid mixture of ferric sulphate and potassium ferricyanide causes the development of an adherent blue precipitate on pyrite, as well as on marcasite, chalcopyrite, and pyrrhotite. That this precipitate adheres in a very thin film seems to be evidence that the minerals function in the reaction.

As pyrite, therefore, is capable of slowly reducing ferric sulphate, it is obvious that any electric action which could arise from the oxidizing power of ferric sulphate would occur chiefly on account of the fact that pyrite enters into direct action very sluggishly—that is, the electric reduction of the ferric solution may occur far more readily under some circumstances than direct reduction by the pyrite. With the more attackable minerals the possibility of electric action would be less than with pyrite, but sufficient experimental evidence has been presented above to show that appreciable currents may be developed by various combinations of solutions and minerals. There

is always the possibility that electric action may be a more ready way of equalizing chemical differences than direct action. This possibility is in accord with the statement of Becker that it appears to be a law of nature for available energy to be expended as rapidly as possible. Accordingly, chemical energy should be converted into electric energy whenever the attainment of equilibrium would be thereby hastened. Becker has called this a principle of maximum dissipativity.[1]

In addition to the ever-present chemical sources of electric currents in the earth, mention may be made of the fact that sulphides are capable of developing thermoelectromotive forces, a subject which has been investigated by A. Abt,[2] who gives the following thermoelectric series:

Abt's thermoelectric series.

1. Chalcopyrite.	8. Nickel ore.
2. Pyrolusite.	9. Arc-light carbon.
3. Bismuth.	10. Iron.
4. Zinc.	11. Pyrrhotite.
5. Nickel.	12. Antimony.
6. Copper.	13. Pyrite.
7. Cadmium.	

Diffusion is also capable of developing electric currents and is the cause of potentials between different solutions. These facts are sufficient to justify a study of the behavior of minerals under electric influences.

The fact that appreciable earth currents have seldom been found at any given point does not exclude the possibility that local electric action may be a potent agency in hastening chemical adjustments, or that very small currents acting for long periods would be capable of accomplishing great results. Of course present conditions in the earth are the result of adjustments and readjustments which have been going on for ages. The same forces are available now as always, but ore deposits may represent the result of very long accumulation. It would be incorrect to say that the electric batteries have run down, but, on the other hand, we can hardly expect to find batteries in the field comparable in intensity with those which we can construct in the laboratory. The laboratory results enable us to detect the tendencies at work. Where the action is distributed over a vast distance it appears that even the best experimentation might be unable to detect the action going on.

It will be desirable to discuss separately the several parts of such circuits as those suggested, consisting of various solutions and min-

[1] Becker, G. F., A new law of thermochemistry: Am. Jour. Sci., 3d ser., vol. 31, p. 120, 1886.

[2] Abt, A., Thermoelectromotive force of some metal oxides and metal sulphides in combination with one another and with simple metals with 100° difference of temperature of the contact points: Annalen der Physik, 4th ser., vol. 2, p. 266, 1900.

erals. The part requiring the least attention for the present purpose is the liquid connection, for it is well known that solutions of inorganic substances, although varying in conductivity with their nature, concentration, and temperature, are on the whole good conductors of electricity.[1] One important point, however, must be emphasized. A current in a solution is due to the actual movement of ions through the solution, a subject thoroughly studied by Hittorf as long ago as 1850. The positively charged cations move in one direction, the direction usually called the "current," the negatively charged anions in the opposite direction. It follows from this that wherever electric currents flow in liquid circuits the cations migrate in one direction, the anions in another. For example, an electric current passing up a vein solution would actually consist in the transport of cations upward and of anions downward in the vein solution. Either migration or interchange of ions would also necessarily occur in "local action."

EFFECT OF A CURRENT FROM SOLUTION TO MINERAL.

METHOD OF EXPERIMENT.

A current flowing from a solution to an electrode makes a cathode combination, and according to the well-known principles of electrochemistry, must be accompanied by "reduction." The chief question that arises is whether the reduction affects the constituents of the solution or the mineral forming the electrode. Experiments to determine this point were made in two ways: First, fairly large currents—several hundredths of an ampere—were applied from an outside source; second, more feeble currents were employed—a few milliamperes, such currents as might actually be generated by the combinations already described.

EFFECTS AT THE CATHODE WITH MODERATE CURRENTS.

Ferric sulphate solution in contact with pyrite was reduced. In dilute sulphuric acid hydrogen and a trace of hydrogen sulphide were evolved. The smooth crystal faces of the pyrite appeared to be irregularly corroded, minute cavities being distributed over their surfaces. Iron was electroplated upon pyrite from a solution of ferrous sulphate, copper from cupric sulphate, silver from silver sulphate, gold from a solution of chlorauric acid, and platinum from a solution of chlorplatinic acid. A piece of pyrite weighing 35 grams was made cathode for five hours in a weak solution of sodium carbonate with a current of 0.04 ampere. The specimen remained bright and lost only 0.0025 gram. Hydrogen was evolved. From caustic soda or sodium sulphide solutions hydrogen was also evolved, but very little

[1] On the conductivity of mine walls and veins see Barus, Carl, U. S. Geol. Survey Mon. 3, p. 345, 1882. The resistances noted were of the order of thousands of ohms.

or none was evolved from a solution of sodium polysulphide, which suggests that the polysulphide was reduced by the current. With neutral salt solutions, such as those of sodium chloride or sodium sulphate, the solution on electrolysis became alkaline around the cathode.

Marcasite and pyrrhotite behaved much like pyrite as cathodes but were not studied in detail. Galena in sodium sulphate solution suffered some mechanical disintegration along cleavage planes, a fact which suggests that the electric polarization may extend into the minutest capillary spaces. As a result of the action sodium sulphide was formed in the solution. The electrolysis of cathodes of galena in normal sodium hydroxide was stated by Bernfeld to yield one equivalent of metallic lead for each equivalent of sulphur set free or passing into solution.[1]

Magnetite was reduced very slowly if at all in the solutions tried.

Pyrolusite is known to be readily reduced when acting as cathode, its use as depolarizer in the Leclanché cell depending on this fact.

EFFECTS AT THE CATHODE WITH FEEBLE CURRENTS.

Ferric sulphate in contact with pyrite was reduced. Gold, platinum, silver, and mercury were precipitated from their soluble salts in metallic form on pyrite. The products resulting from sulphuric acid with pyrite, as far as they could be identified, were hydrogen, some hydrogen sulphide, and ferrous sulphate. The pyrite appeared to remain bright and untarnished, however. With sodium chloride and pyrite hydrogen was evolved and the solution became alkaline and showed a trace of soluble sulphide. When cupric sulphate was electrolyzed, if the solution was neutral, some copper was deposited; but under the microscope the copper was seen to shade off into a dark-colored deposit of microscopic cubic crystals which were too small to be identified with certainty. A white precipitate, presumably basic sulphate, was also formed in the solution. No evolution of gas occurred. In a solution that was weakly acid and free from chlorides copper was the first visible product observable on the pyrite. In the presence of chlorides, however, a film consisting of microscopic tetrahedra appeared on the surface of the pyrite, and this film proved to be cuprous chloride.

The time at my disposal has not been sufficient to enable me to make some other experiments of this kind, especially with feeble currents, and the effects obtained might in some experiments differ from the effects produced by larger currents on account of the slow rate at which the very insoluble minerals react with cold solutions.

[1] Bernfeld, I., Studien über Schwefelmetallelektroden: Zeitschr. physikal. Chemie, vol. 25, p. 53, 1898.

The experiments made indicate that the changes consist principally in a reduction of the constituents of solutions in contact with pyrite. Other possible effects are the deposition of free metals, the formation of hydrogen sulphide, the development of alkalinity, or the evolution of hydrogen or hydrogen sulphide. The sulphides at least are much more resistant as cathodes than as anodes, as will be next shown.

EFFECT OF A CURRENT FROM MINERAL TO SOLUTION.

When sulphides function as anodes they are attacked much more vigorously than when they function as cathodes. Thus pyrite lost fifty times as much in weight with the same current when anode as when cathode in dilute sodium carbonate solution, and seven times as much in dilute nitric-acid solution. Pyrrhotite lost seven times as much when anode in sodium sulphide solution as when cathode.

The loss of weight of a pyrite anode in a solution of sodium carbonate, in spite of the fact that it became coated with ferric hydroxide, must have been due to oxidation and solution of the sulphur, which was converted, in part at least, into sulphate, thus showing that both constituents of the pyrite were oxidized. Anodes of pyrite in a solution of sodium sulphide were immediately blackened by ferrous sulphide, which was formed as soon as current was applied. A pyrite anode in a solution of copper sulphate became coated with black iridescent copper sulphide. Under similar conditions with a solution of ferrous sulphate, the anode suffered very little change in weight and extremely slight discoloration, the chief effect of the current consisting in the oxidation of the ferrous sulphate. As compared with its behavior in a solution of sodium sulphide or any other metallic salt the behavior of pyrite in a solution of ferrous sulphate suggests a sort of simultaneous decomposition and regeneration of the pyrite, the net result being hardly noticeable.

In acid solutions no oxygen was evolved on anodes of pyrite with currents of slight intensity. Instead, iron passed into solution as ferric salt. Part of the sulphur was oxidized to sulphate; the rest remained on the anode in the free state. The electrode was noticeably tarnished by films of various shades—gray, purple, and black—the color changing in the order indicated as the experiment was continued.

In some of these experiments higher potentials were applied than those produced by natural combinations, and the results must be judged accordingly and taken as suggestions of the tendencies at cathode and anode respectively. Further study along this line should be made by those who are interested in special problems likely to be related to the phenomena.

ELECTRIC CONDUCTIVITY OF MINERALS.

Another part of the suggested circuit is formed by the mineral conductors. Fox, whose early study of the electric activity of mineral veins has already been cited, determined that pyrite, arsenical pyrite, galena, pyrolusite, and tetrahedrite are conductors of electricity; that molybdenite is a very imperfect conductor; and that argentite, cinnabar, stibnite, bismuthinite, realgar, and blende are nonconductors. Later observers added other minerals to these categories from time to time.

A very complete list of conducting minerals has recently been compiled by H. A. Wentworth[1] from a study of their behavior during electrostatic concentration. The theory of electrostatic separation is that fine particles of most substances are attracted toward an electrically charged body, but that only those that are conductive will acquire the same charge and be repelled. If this theory is correct it should be possible to set down a list of the conductive minerals by observing their electrostatic behavior. Wentworth's list is as follows:

Conducting and nonconducting minerals.

Good conductors.

Argentite	Galena	Psilomelane
Arsenic, native	Graphite	Pyrargyrite
Arsenopyrite	Hausmannite	Pyrite
Bismuth, native	Hematite	Pyrolusite
Bismuthinite	Ilmenite	Pyrrhotite
Bornite	Jamesonite	Redruthite
Brookite	Leucopyrite	Silicon
Calaverite	Linnæite	Smaltite
Carborundum	Magnetite	Sperrylite
Chalcopyrite	Manganite	Stannite
Chalcocite	Marcasite	Stephanite
Cobaltite	Mercury, native	Sylvanite
Copper, native	Millerite	Tellurium
Covellite	Molybdenite	Tetrahedrite
Enargite	Niccolite	Wad
Ferrosilicon	Pentlandite	Wolframite
Franklinite	Proustite	Zincite

Poor conductors.

Zinc blende	Garnet	Nearly all the silicates, carbonates, and sulphates.
Quartz	Apatite	Most of the siliceous rocks.
Feldspar	Rutile	
Epidote		

[1] Wentworth, H. A., Electrostatic concentration or separation of ores: Am. Inst. Min. Eng. Bull. 66, p. 642, 1912.

The tables of Landolt-Börnstein-Meyerhoffer (1905) give the following values for the conductivities of a few minerals and conducting solids in reciprocal ohms.

Conductivity of minerals in reciprocal ohms.

Substance.	Temperature.	Conductivity.
	° *C.*	
Mercury	25	10,386
PbS	20.7	3,470
Siberian graphite	15	820
Nickel ore	20	313
Pyrrhotite	20	119
Cu_2S powder	0	91
FeS	0	8.98
Magnetite	19	1.68
Hematite	0	1.24 2.41
Chalcopyrite	20	.98
MnO_2	0	.16
Co_2O_3	18	.013

The data in the table are obviously scanty and in part indefinite. Large variations are to be expected on account of inclusions, and small quantities of a second constituent may be sufficient to transform a nonconducting mineral into a fair conductor; sphalerite, for example, seems to possess conductivity by virtue of its content of ferrous sulphide.

It was pointed out by Braun [1] that the conductivity of some minerals is a function of the direction and time of passage of the current. Dufet [2] took exception to these conclusions, which were supported later, however, by the work of Bernfeld [3] on galena.

The conductivity of some sulphides increases with a rise of temperature, as in electrolytic conductors, the behavior of silver sulphide in this respect having been noted by Faraday.[4] The suggestion has been made that the passage of a current in these sulphides causes them to decompose into their elements, but no such decomposition could be observed by Bernfeld with galena. In some experiments heretofore made the contacts used in mounting sulphides for tests have been the chief source of irregularities in their conductivity.[5] At high temperatures even silicates possess appreciable electric conductivity. It thus appears that a very large number of minerals are susceptible to electric influences.

[1] Braun, F., Ueber die Stromleitung durch Schwefelmetalle: Poggendorff's Annalen, vol. 153, p. 556, 1874.
[2] Dufet, H., Sur la conductibilité électrique de la pyrite: Compt. Rend., vol. 81, p. 628, 1875.
[3] Bernfeld, I., Studien über Schwefelmetallelektroden: Zeitschr. physikal. Chemie, vol. 25, p. 50, 1898.
[4] Poggendorff's Annalen, vol. 31, p. 242, 1834.
[5] Hayes, H. V., Note on the electrical conductivity of argentic sulphide: Am. Acad. Arts and Sci. Proc., vol. 46, p. 613, 1910.

DETAILED STUDY OF VARIOUS POTENTIALS.

GENERAL RESULTS OF THE MEASUREMENTS.

The object so far has been to establish and exemplify the proposition that electric currents may be generated in the earth and bring about chemical effects. We must now, somewhat more theoretically, consider the relations between electromotive forces and minerals, and must attempt to explain them consistently and point out the conditions under which they are constant and reproducible. In this connection it may be mentioned that measurements of electromotive force are quantitative expressions of physical or chemical differences between different systems—differences made evident by a proper separation of the systems. When the systems are properly separated the tendency toward electric equalization between them may easily be measured. By union or mixture of the systems the differences would generally be equalized without visible electric action.

The most general statement that can be made about the potentials shown by minerals in different solutions is that the potentials are chiefly determined by the solutions. Without denying that there may be specific effects due to the minerals themselves it may be positively stated that the effect produced on the potentials by changing the solutions is enormously greater than the effect of changing the minerals. This is of course due partly to the fact that wide variations in the concentrations of the effective constituents are possible in different solutions.

The very great similarity of all the potentials noted with mineral electrodes to "oxidation and reduction" potentials has already been pointed out. When substances capable of giving such potentials to inert electrodes are present in relatively large amount in a solution in contact with minerals, very constant potentials may generally be developed, but the action of the mineral is then scarcely more than that of an electric conductor, as the amount of oxidizable or reducible material in the solution is so large. Such combinations are not adapted to show differences between minerals, although the data obtained by the experiments may aid in elucidating the chemistry of ores. The following values were obtained with various iron sulphides in a mixture of ferric and ferrous sulphates. The measurements were all made by the usual compensation method of Poggendorff, and the values of the single potentials are referred to the normal calomel electrode without correction for liquid potentials. The minerals, supported by suitable clamps, were partly immersed in the solutions and connection was made to the calomel electrode by a U tube filled with normal potassium chloride.

Potentials shown by iron sulphides in ferric-ferrous sulphate solutions.

Substance.	Time.	Volt.
	Minutes.	
Pyrite in {$FeSO_4$ (0.1 normal), $Fe_2(SO_4)_3$ (0.1 normal), H_2SO_4 (0.18 normal)}	1	0.939
	12	.935
	29	.939
	120	.926
Pyrite from Elba in same solution	1	.933
	7	.925
	78	.929
Pyrite collected by Julien	....	.939
Marcasite from Joplin	....	.934
Pyrrhotite from Ducktown	....	.932
Marcasite collected by Howell	....	.932
Nodule from Florida	....	.939
Pyrite in above solution diluted 10 times	....	.946
Marcasite in above solution diluted 10 times	....	.940
Pyrrhotite in above solution diluted 10 times	....	.908
Pyrite in {$FeSO_4$ (0.95 normal), $Fe_2(SO_4)_3$ (0.056 normal), H_2SO_4 (0.102 normal)}	1	.850
	32	.852
	45	.852
	[a] 24	.866

[a] Hours.

These results show that under the conditions of the experiments the ferric-ferrous potential practically overcame any differences in

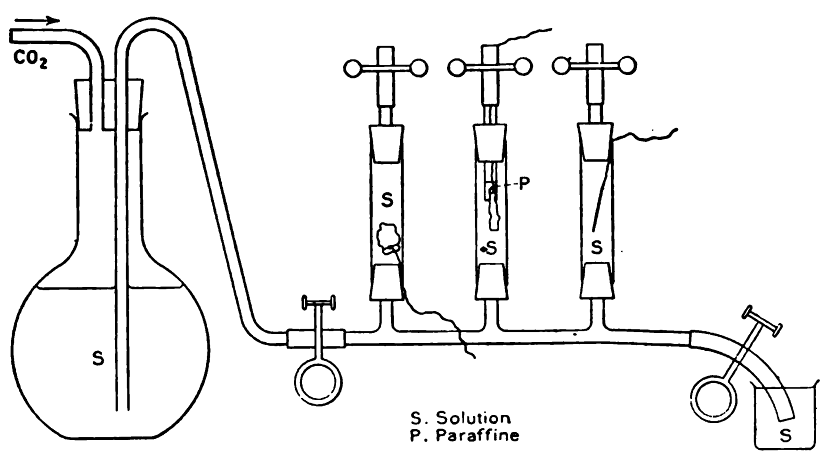


FIGURE 2.—Method of supplying fresh solution to mineral electrodes without affording access of air.

the iron sulphides. In one experiment pyrrhotite gave a lower value, presumably because of the reduction of ferric salt by the hydrogen sulphide formed. That a similar effect occurred to a lesser degree with the other sulphides is at least suggested by the fact that the values are slightly lower than those computed by the equation on page 12, although it is difficult to make a good evaluation of the ionic concentrations in the rather concentrated sulphate solutions. The suggestion that the sulphides slowly reduce ferric sulphate is correct, however, if less concentrated solutions are employed, and, as will be shown later, ferric sulphate is incompatible with most sulphides.

An effort was made to determine some potentials in a neutral solution of ferrous sulphate wholly free from ferric salt. For this purpose a concentrated solution of ferrous sulphate was prepared and preserved in contact with iron wire in a closed flask fitted with a siphon. An atmosphere of carbon dioxide was maintained in the flask (fig. 2). This solution could be delivered to tubes in which the electrodes were placed. For the sake of comparison a smooth platinum electrode was introduced into a third tube. From time to time fresh solution was allowed to flow over the minerals. At first bubbles of gas appeared on the sulphides, but in the course of time these dissolved. The results are stated in columns headed "A," under the headings "Pyrite" and "Marcasite." To test whether the platinum wires obscured any effect of the sulphides, specimens of the sulphides were attached to platinum wire and the exposed platinum was then wholly covered with paraffin. These specimens gave the results shown in the columns headed "B," under "Pyrite" and "Marcasite," which are practically identical with those shown in the columns headed "A."

Potentials in 3.7 normal ferrous sulphate.

Time.	Pyrite.		Marcasite.		Platinum.	Galena.
	A	B	A	B		
	Volt.	*Volt.*	*Volt.*	*Volt.*	*Volt.*	*Volt.*
0.1 hour	0.52	....	0.32	....	0.10	....
0.6 hour	.48	....	.38	....	.08	....
1 hour	.61	....	.43	....	.13	....
2 hours	.57	0.67	.46	0.73	.21	....
4 hours	.58	....	.52	....	.34	....
22 hours	.59	....	.60	....	.55	....
24 hours	.62	.64	.61	.62	.59	0.56
31 hours	.63	....	.58	....	.55	....
48 hours	.64	.62	.61	.59	.62	.52
72 hours	.61	.44	.62	.44	.60	.51
96 hours	.49	.43	.48	.44	.48	.53
120 hours	.43	....	.47	....	.47	....

Although no satisfactory explanation of these results can be given, it appears that pyrite, marcasite, and platinum present no significant differences. Evidently such changes as were going on in the solutions were influenced in only a secondary way by the minerals. Galena, however, appeared to maintain a more constant value. The values may possibly be interpreted as ferric-ferrous potentials, in which the concentration of ferric salt was reduced to a constant point.

The following potentials were obtained in normal sodium hydrosulphide saturated with hydrogen sulphide at atmospheric pressure. The specimens were supported in small bottles, as shown in figure 3, the platinum wire being well paraffined and the bottles closed except when measurements were made.

Potentials in normal sodium hydrosulphide.

Time.	Pyrite.	Marcasite.	Pyrrhotite.	Chalcopyrite.	Galena.	Platinum.
	Volt.	*Volt.*	*Volt.*	*Volt.*	*Volt.*	*Volt.*
0.1 hour	−0.02	−0.03	−0.02	−0.02	−0.04	....
2 hours	− .01	− .03	− .03	− .02	− .04	−0.01
24 hours	− .02	− .03	− .03	− .03	− .03	− .04
11 days	− .03	− .03	− .04	....	− .03	− .02

To assume that the small differences here shown should be ascribed to differences in the respective minerals would be unwarranted. Rather it appears that the minerals, as well as platinum, merely served as conductors for the attainment of a fairly constant potential of the sodium hydrosulphide. Under these conditions, although the minerals are in a polarized state, there is little, if any, indication that one mineral is more stable than another. Electric activity under these circumstances would affect chiefly the solution rather than the minerals.

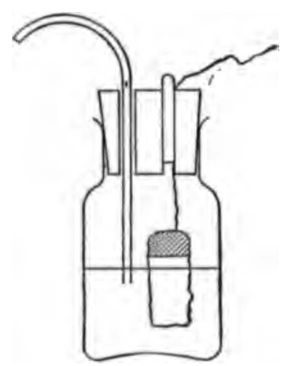


FIGURE 3.—Half cell of mineral suspended in a solution for observation over a long period.

Many attempts were made to obtain characteristic potentials of the different minerals in the absence of such pronounced oxidizing and reducing solutions as those above mentioned.

The only positive results obtained at first were that one group of sulphides, including pyrite, marcasite, and chalcopyrite, gave potentials higher by one or two tenths of a volt than another group which included pyrrhotite and galena. None of the specimens of sphalerite examined had enough conductivity to yield a result. In attempting to differentiate pyrite, marcasite, and chalcopyrite it was found that the differences between the minerals were of the same order as the differences between different specimens of the same mineral, and that none of their potentials was much removed from that shown by smooth platinum similarly treated. Of course all minerals have some solubility, so that no matter what other substances there may be in a solution the products resulting from the minerals must also be present. As these products are in general oxidizable or reducible ions, the conclusion is inevitable that the potential of most minerals will be of the nature of an oxidation and reduction potential. We thus return to the thought that even if the minerals have specific potential differences the effect of their solution products on the potential can not be neglected, and this effect may in fact be all there is to the "potential of a mineral" in water. If pure water could be saturated with only the solution products of a pure mineral the problem would be easy,

but in practice the complete removal of foreign substances from the water and the mineral is extremely difficult if not impossible.

The potential shown by some specimens of a given mineral depends considerably on the previous treatment of the specimens, the explanation of the differences found being that if a mineral is long immersed in a solution some of the solution penetrates its invisible pores and subsequently diffuses out very slowly when the mineral is placed in another solution. When once the pores are filled with water or an indifferent electrolyte the mineral is almost as responsive as a platinum electrode to changes in acidity or concentration of the solution; that is, to such changes as determine the equilibria of the effective ions in the solution.

To what extent observed potentials may be ascribed to minerals, as distinguished from the solutions in contact with them, will best appear, however, from the detailed measurements that follow.

MEASUREMENTS OF POTENTIAL ASSUMED BY CERTAIN MINERALS.

PYROLUSITE.

Electrodes of manganese dioxide were studied by Tower,[1] who prepared them by precipitating manganese oxide upon platinum anodes by electrolysis. In order to develop a theory of the potential of the electrode, the solution bathing the electrode was assumed to contain manganous ions. The possible presence of manganese ions of higher valence was apparently not considered by Tower. He proved that the potential of such electrodes depends on the concentration of acid and manganese salt in the solution, the effect of acid being fourfold that of the manganese salt. An increase of acid raises the potential; an increase of manganese salt lowers it. Some of his values are given in the following table:

Potential of manganese dioxide in various solutions at 14° C. as determined by Tower.

	Volts.
0.1 normal NaOH	0.70
0.0125 normal NaOH	.75
0.00156 normal NaOH	.80
0.000391 normal NaOH	.84
Neutral 0.01 normal $Mn(NO_3)_2$	.87
0.00195 normal H_2SO_4, 0.2 normal $Mn(NO_3)_2$	1.44
Normal H_2SO_4, 0.1 normal $Mn(NO_3)_2$	1.72
Normal H_2SO_4, 0.000391 normal $MnSO_4$	1.80
0.000977 normal H_2SO_4, normal $MnSO_4$	1.44
0.99 normal H_2SO_4, 0.000782 normal $MnSO_4$	1.79

A number of measurements were made by the writer on natural specimens of various oxides of manganese, some of which were said to be pyrolusite and others known to be manganite, but the potentials observed agreed only in part with those recorded by Tower.

[1] Tower, O. F., Studien über Superoxyd-Elektroden: Zeitschr. physikal. Chemie, vol. 18, pp. 17–50, 1895.

The following values were noted with small splinters, said to be pyrolusite, from Germany. Constancy was obtained in from half an hour to an hour.

Potential of small splinters said to be pyrolusite.

Electrolyte.	1	2
	Volts.	*Volts.*
0.1 normal NaOH, saturated with the mineral	[a] 0.52	0.70
0.0125 normal NaOH	.74	.75
0.00625 normal NaOH	.72	.77
0.99 normal H_2SO_4, 0.00078 normal $MnSO_4$	1.05	1.79
0.00781 normal H_2SO_4, 0.0992 normal $MnSO_4$	1.10	1.54

[a] Indefinite.

1. Potential obtained by me.
2. Electrolytic MnO_2, Tower, O. F., op. cit.

In explanation of these results it should be mentioned that pyrolusite is not a well-crystallized species. The crystalline native manganese dioxide is pollianite, which could not be obtained for study. A massive specimen of pyrolusite from Rio Apache, N. Mex. (U. S. National Museum No. 8424), gave the following potentials:

Potential of massive pyrolusite from Rio Apache, N. Mex.

Electrolyte.	1	2
	Volts.	*Volts.*
0.00781 normal H_2SO_4, 0.0992 normal $MnSO_4$	1.22	1.54
0.00625 normal NaOH	.96	.76

1. Potential obtained by the writer.
2. Potential obtained for MnO_2 by Tower, op. cit.

This specimen did not come to constancy quickly as did Tower's electrodes on platinum. Another difficulty with this mineral was due to capillarity as manifested in the tendency of the solution to rise up through the mineral and wet the holder.

A very excellent specimen of crystallized manganite from Ilefeld, Hanover, Germany (U. S. National Museum No. 45630), proved to be too nonconducting to permit measurements to be made. Another specimen of the same mineral, however, which had a radiating structure, from Markhamville, Kings County, New Brunswick (U. S. National Museum No. 45711), was sufficiently conducting. When this manganite and the pyrolusite previously mentioned were immersed in the same solution the values shown were as follows:

Potential of manganite and pyrolusite.

Electrolyte.	Manganite.	Pyrolusite.
	Volts.	*Volts.*
Normal KCl, 0.01 normal $MnSO_4$, 0.01 normal H_2SO_4	1.05	[illegible]
Normal KCl	[illegible]	1.11

The above values are at least in the direction which would be expected—the higher potential for the higher oxide. The potentials obtained in a solution of potassium chloride in the presence of air are the highest observed with any of the minerals investigated and indicate that, when coupled with any other mineral in the presence of air, the manganese mineral would be the cathode; that is, the other mineral would be oxidized by electrolytic action, if it occurred. It was found that pyrolusite is far less easily polarized as cathode than the other minerals studied, a fact which is perfectly consistent with the use of pyrolusite as a depolarizer in the well-known Leclanché battery.

PYRITE.

The preliminary observations on pyrite showed that its potential is chiefly dependent on the nature of the solution in which it is immersed. In order to determine the effect of changes in the concentration of these solutions the following experiments were performed:

A fresh specimen was immersed in tenth normal, hundredth normal, and thousandth normal sulphuric acid successively, each solution containing about one-fifth of 1 per cent of ferrous sulphate. The three potentials were 0.82, 0.83, and 0.82 volt, respectively, showing at most a very slight dependence on the acid concentration. But with similar variations in the ferrous sulphate content of the solution the potentials were 0.78, 0.81, and 0.84 volt, respectively. The ferrous sulphate solutions each contained a small amount of sulphuric acid. The differences caused by a tenfold change in content of ferrous ion are decidedly greater than those resulting from changes in acidity. Similar results were obtained with ferric sulphate, the potentials being 1.04, 1.08, and 1.11, respectively. The potentials in even dilute ferric sulphate are strikingly high. These results furnish valuable suggestions for the interpretation of the phenomena. When ferrous and ferric salts are present together we are apparently dealing, in part at least, with a "ferrous-ferric" potential, as was pointed out on page 27.

The potential of pyrite is plainly affected by changes in the hydroxide or sulphide concentration of alkaline solutions, the record presenting a marked contrast to that obtained by changes in acid solutions. The following results show the variation caused by tenfold changes:

Potential of pyrite in alkaline solutions.

Solution.	NaOH.	Na_2S_x.
	Volt.	*Volt.*
Normal	0.32	—0.07
0.1 normal	.38	—.01
0.01 normal	.44	+.09
0.001 normal	.51	+.15

Similar effects were noted in solutions of sodium sulphide and sodium hydrosulphide.

The question at once arises whether the hydroxide and sulphide concentrations affect the potential merely by determining the iron content or sulphide content, according to the law of the solubility product or some other similar law, or whether they affect the potential in a direct way; in short, whether pyrite can be considered a "compound electrode." If it can be so considered, the relation between its potential and the concentrations can be expressed by the following equation:

$$E = E_0 + \frac{RT}{nF} \ln [Fe]\ [S]^2.$$

There are several difficulties in verifying such an equation. In the first place, with access of air some ferric salt is formed in spite of the presence of the electrode. With the ferric salt present there is the complication of the "ferrous-ferric" potential. Even closed receptacles, boiled solutions, and an atmosphere of carbon dioxide appear to be insufficient to eliminate all ferric salt; enough persists to yield a relatively high potential. Such a potential might also be due to polysulphide ions, which are doubtless formed from pyrite. In an atmosphere of hydrogen it appears that enough normal sulphide is formed to lower the potential appreciably. With even a small concentration of sulphide ion the potential is considerably lowered, but under these conditions a variation of the concentration of ferrous ion (in acid solution) appears to have no effect upon the potential. This was proved by measurements upon marcasite (see below), but the results would probably have been similar for pyrite. The relations of the solubility product of these disulphides are unknown. Lastly, it is very doubtful whether such electrodes can be considered strictly reversible. Whether both atoms of sulphur may function electrically or not has not yet been determined. The presumption is that only one does. When the pyrite is anode there is a very strong tendency toward oxidation of ferrous ion and of sulphur to sulphate—the last action overstepping the limit of reversibility—although as cathode soluble sulphide is formed. Neither set of conditions is wholly favorable for the maintenance of the pyrite. In view of these difficulties any application of the equation must rest upon a good many assumptions and will not be attempted at present. At the same time it is hoped that the potential will some day be expressed by a formula which will be an advance over the present empirical statement of the potential in "water."

For the next experiment, instead of adding any of the constituents of pyrite to the solution, the attempt was made to obtain definite results by letting the pyrite supply its own solution products. If only water

is used there will be a considerable liquid potential to be reckoned with, and on this account it seemed better to use neutral salt solutions. The following table gives a record of the behavior of pyrite dipping in normal potassium chloride in a small closed bottle (fig. 3, p. 29) for over a month:

Potential of pyrite in normal potassium chloride in presence of air.

Time.	Volt.	Time.	Volt.
1 minute	0.76	2 days	0.66
5 minutes	.76	3 days	.64
30 minutes	.74	5 days	.63
1 hour	.74	7 days	.66
3 hours	.72	9 days	.66
5 hours	.69	14 days	.66
12 hours	.69	40 days	.71
1 day	.69		

The above results show a slow fall for several hours and thereafter a considerable degree of constancy in the period from 2 to 14 days. Unfortunately, however, other specimens gave different values. Even the same specimen after being dried gave slightly different values at different times when first placed in the solution. The variations thus noted are illustrated by the following results:

Variations of potential in normal potassium chloride due to accidental causes.

Date.	1	2	3	4
	Volt.	*Volt.*	*Volt.*	*Volt.*
Apr. 11	1.01	0.96	0.94	0.72
May 4	.99	.92	.88	.71
June 14	.93	.88	.87	.68
June 18	.94	.88	.85	.83
June 25	.97	1.00	.83	[a] .56

[a] This measurement is evidently erroneous.

1. Pyrite collected by A. A. Julien (No. 39).
2. Pyrite from Elba.
3. Octahedron of pyrite, French Creek, Pa.
4. Marcasite, cockscomb, collected in Missouri by C. E. Siebenthal.

In order to see if the presence of air could account for these irregularities a solution of potassium chloride was boiled to free it from air as far as possible. While still warm it was transferred to a flask connected with a siphon, through which it could be delivered to the tubes containing the specimens under investigation. A platinum wire was bound around the specimens and led out between the stoppers and the glass. For the sake of comparison a smooth platinum electrode was introduced into one of the tubes. From time to time fresh solution was allowed to flow over the electrodes. Carbon dioxide from a generator replaced the solution as it was used. The

apparatus was the same as described on page 27. The results were as follows:

Potentials of specimens immersed in potassium chloride solution containing CO_2 at 25° C.

Time.	Pyrite.		Marcasite.		Platinum.	Galena.
	A.	B.	A.	B.		
	Volt.	*Volt.*	*Volt.*	*Volt.*	*Volt.*	*Volt.*
1 hour	0.67	0.66	0.66	0.78	0.62	0.52
1 day	.69	.65	.70	.71	.60	.55
2 days	.68	.71	.76	.72	.56	.51
5 days	.63	.59	.70	.72	.65	.53
8 days	.62	.61	.70	.71	.65	.52
11 days	.64	.62	.70	.71	.60	.52

The preceding results suggest that in their electromotive behavior pyrite and marcasite function chiefly as "unattackable electrodes," as their potentials do not vary greatly from those shown by smooth platinum. That the effect was not due to the platinum wires was carefully determined in every experiment by attaching long pieces of several specimens to platinum wires and then completely covering the platinum and a portion of the mineral with paraffin. The results were practically identical with the preceding ones.

The minerals were examined in potassium chloride solution with still greater precautions against the presence of air by the use of tubes in which the solution was boiled out directly, thus avoiding the necessity of transfer (fig. 4). The results of these measurements were as follows:

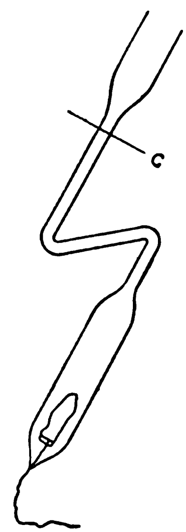


FIGURE 4.—Apparatus for boiling out air under reduced pressure before measuring electromotive force, the tube to be broken off at C.

Potentials of specimens immersed in potassium chloride solution boiled out directly.

Time.	Pyrite.	Chalcopyrite.	Marcasite.	Platinum.
	Volt.	*Volt.*	*Volt.*	*Volt.*
1 day			0.60	
2 days	0.64	0.64	.60	0.69
3 days	.63	.64	.60	.69
4 days	.64	.66		.69
5 days	.63	.67		.69
6 days			.59	

The conclusion from the preceding experiments is that the exclusion of air lowered the potentials slightly. A much better exclusion of air was finally accomplished, however, by supporting the specimens in a bottle through which a slow current of very pure hydrogen was carried as long as desired. This brought the potential of pyrite down to values ranging from 0.30 to 0.55 volt according to the length of treatment. It seems impossible to avoid the conclusion, therefore, that a trace of ferric salt is very persistent unless particular care is used to exclude it or reduce it, and that the potentials in air and in the absence of air may differ markedly on account of the presence of ferric salt. The unavoidable accidental variations shown by pyrite in neutral salt solutions are probably due, therefore, to indeterminate traces of ferric salt. The hypothesis that polysulphide ions are present in varying proportion to sulphide ions is equally plausible and will presently be considered.

Instead of trying to obtain the potential in a neutral solution, a state not easily obtained with reference to the ionization of water, one may reduce the number of variables slightly by measuring the potentials in acid and alkaline solutions of definite concentration and taking the mean value for neutrality. Liquid potentials were largely eliminated by having the solutions about normal with potassium chloride, and as the value 0.83 volt was obtained in tenth-normal sulphuric acid and 0.38 in tenth-normal sodium hydroxide we should obtain 0.60 at the neutral point for the potential of pyrite in normal sodium sulphate solution in the presence of air, assuming the relation to be linear. The values actually obtained in neutral salt solutions under these conditions ranged around 0.72. In hydrogen the two values obtained for tenth-normal solutions were 0.44 and 0.13 volt, respectively, giving a mean of 0.28 volt for the potential of pyrite in a neutral salt solution in the presence of hydrogen.

It was thought that the experiments in hydrogen might have overshot the mark by producing some hydrogen sulphide, and this was found to be the case. Some powdered galena was moistened and placed in a small wash bottle with a glass stopper and the bottle filled with hydrogen. A strip of clean silver suspended in the bottle showed a slight tarnish in a few hours. Evidently, then, hydrogen is too vigorous a reducing agent for the purpose of merely excluding air.

The extreme delicacy of the conditions determining the potential shown by pyrite in normal potassium chloride solution is further illustrated by the ease of its polarization. With a potential of 0.78 volt at the beginning, pyrite was polarized by a very small current, 0.000005 ampere, copper in copper sulphate being used as an auxiliary electrode. The polarizing potential was probably not over 0.3 volt. In 15 minutes the potential of the pyrite had fallen to 0.57 and after-

ward remained fairly constant at 0.51. Under these conditions the pyrite was probably surrounded by a film containing very little ferric salt. Upon stopping the polarization the potential rose in half an hour to 0.75 again. The pyrite was then polarized similarly as anode. The potential rose to about 0.97 and remained fairly constant. This probably corresponded to a maximum of ferric salt under the conditions of the experiment. When the polarization was stopped the potential soon fell to 0.80. With this specimen, therefore, under

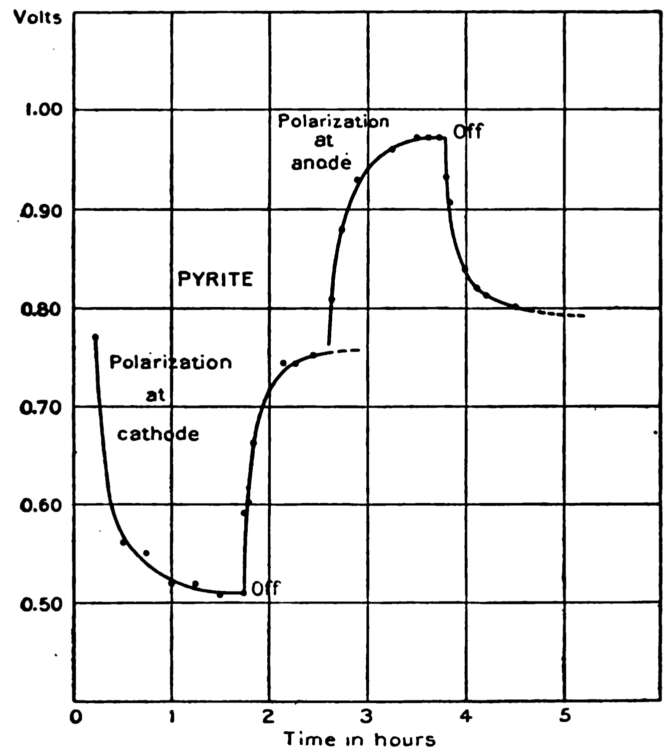


FIGURE 5.—Curves showing rate of polarization. Applied electromotive force about 0.3 volt; current, 0.000005 ampere.

these conditions, the potential certainly lay between 0.75 and 0.80. The results are shown graphically in figure 5. We are dealing here with a potential which is extremely sensitive to current—that is, the electrode is very easily polarized. In other words, pyrite furnishes so slight a concentration of its characteristic ions that a very feeble current suffices to alter the concentration enormously.

The lag shown by a certain specimen of pyrite in attaining constancy in a new environment is also illustrated by the following results:

Lag in the potential of pyrite when placed in a new environment.

Substance.	Time in hours.	Potential in volts.
Pyrite in 0.1 normal H_2SO_4, in presence of air	0.1	+0.87
	.3	+ .88
	.5	+ .88
Same specimen stood 9 days in normal NaSH at	....	− .03
Same specimen placed in 0.1 normal H_2SO_4, in presence of air	.5	+ .57
	1.0	+ .61
	2.0	+ .65
	22.0	+ .79
Same specimen placed in 0.1 normal H_2SO_4, air displaced by hydrogen	.6	+ .57
	24.0	+ .44
	96.0	+ .44

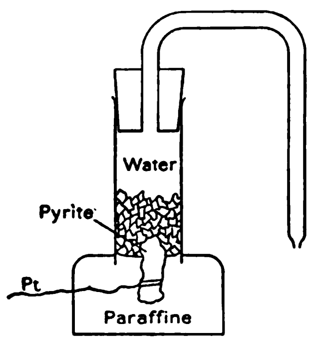


Figure 6.—Mounting of pyrite to obtain a saturated solution over a long period without access of air.

The arrangement shown in figure 6 is believed to be the best one devised for mounting pyrite in such a way as to attain its own characteristic potential in water. A good-sized piece of pyrite was attached to a platinum wire and then partly immersed in a block of paraffin. A tube about an inch in diameter was then sunk in the paraffin, forming a water-tight holder. The pyrite in pure water was surrounded with coarsely powdered pyrite for a height of an inch. The potential shown by this pyrite was as follows:

Potential of pyrite in water.

Time.	Volt.	Time.	Volt.
Start	0.90	13 days	0.75
15 minutes	.89	Fresh water added:	
3 hours	.87	1 day	.74
1 day	.83	4 days	.63
4 days	.80	6 days	.62
8 days	.80		

Whatever the solution products of pyrite may be at first, the ions OH^- and SH^- are probably formed to some extent. It seems reasonable to suppose that these ions will attack the sulphur of the pyrite further, and that the progress of these slow, successive reactions accounts for the slow fall of the potential shown by pyrite in water.

After reviewing all the preceding results, the most logical conclusion concerning the potential shown by pyrite in water with access of air is that its high value is due either to ferric salt, to acid produced by the oxygen of the air, or to polysulphide ions. Under these conditions a single electrode of pyrite is incapable of maintaining the iron in the ferrous condition and similarly the sulphide ion is probably oxidized in part, thus assisting in the production of a high potential. Mere traces of ferric ion suffice to give the high value. This explanation is also consistent with the variable results shown by pyrite in a potassium chloride solution.

When air is excluded, on the other hand, a somewhat lower value is obtained, which seems to vary only slightly with the content of ferrous salt but is extremely sensitive to changes in alkalinity or sulphide concentration and may be reduced to a very low value by an excess of alkali sulphide. These low potentials may be termed "sulphide" potentials. The true potential of the solution products of pyrite must be intermediate between the "ferric-ferrous" potentials and the "sulphide" potentials—that is, must be between 0.80 and 0.56. If such a thing were possible, it would appear to be a "ferric-sulphide" potential. It seems impossible, however, with any arrangement of apparatus so far devised, to establish this potential definitely on account of the slow rate at which the pyrite comes into equilibrium with the solutions, and an expression of the potential in terms of an equation has therefore not been found.

MARCASITE.

Experiments were made with marcasite to see if it presented any difference from pyrite. The marcasite was in the form of cockscombs, collected in the Joplin district of Missouri by C. E. Siebenthal, of the United States Geological Survey. By the preliminary method of experimentation in air pyrite seemed to give a higher value at first, but marcasite averaged slightly higher after a time. The mean of a number of determinations for marcasite in normal potassium chloride in the presence of air was 0.80 volt, whereas pyrite gave 0.72 volt. Marcasite is ordinarily considered to be more oxidizable than pyrite. In other words, it should produce ferric sulphate faster than pyrite, and this higher potential, attained after the lapse of an hour or so, seems to agree with the interpretation that the high potential of pyrite and marcasite in the presence of air is due to ferric sulphate or sulphuric acid in the solution. According to this interpretation the real factors in the mechanism of the process would be the rate of oxidation and the rate of supply of oxygen.

The variation of the potential of marcasite with changes in alkalinity and in the nature of the solution in general was found to be similar to that shown by pyrite, within the limit of error of the observations. Several of these comparisons have already been given. The following data form an additional record of the phenomena:

Comparison of potentials of marcasite and pyrite.

	Marcasite.	Pyrite.
	Volt.	*Volt.*
0.1 normal NaOH	0.40	0.38
0.01 normal NaOH	.47	.44
0.001 normal NaOH	.56	.51
Normal KCl, in air (mean of a number of observations)	.80	.72
0.10 normal NaOH, 0.90 normal KCl	.35	.38
0.10 normal H_2SO_4, 0.90 normal KCl	.90	.83
Mean of last two values	.62	.60

On the whole the differences here shown between pyrite and marcasite are of the same order as the error of the determinations; nevertheless, the results indicate a persistent tendency of the marcasite toward a slightly higher value in the presence of air. A difference so slight, however, is of a much lower order than the differences caused in the potential by a variation in the nature of the solutions.

Measurements were made in 0.005 normal sulphuric acid in an atmosphere of hydrogen sulphide, the marcasite being partly submerged and suspended by a fine platinum wire. If the dissociation constant[1] of hydrogen sulphide $[H]^2[S]$ is taken as 1.1×10^{-23} and the hydrogen ion concentration in 0.005 normal sulphuric acid[2] as 0.0043 we should have

$$S^{--}=\frac{1.1\times10^{-23}}{0.000018}=6.1\times10^{-20}$$

This is certainly not an extreme concentration of sulphide to try, although it is insufficient to precipitate ordinary ferrous sulphide. The ferrous ion content was varied from 0.0005 molal to 0.1 molal without any effect upon the potential, as the following results show:

Potential shown by marcasite in acid solutions containing potassium chloride and ferrous sulphate and saturated with hydrogen sulphide.

Formula concentration of $FeSO_4$.	Formula concentration of (H^+).	Formula concentration of (S^{--}).	Potential.
			Volt.
0.0005	0.0043	6.1×10^{-20}	0.292
.001	.0043	6.1×10^{-20}	.292
.01	.0043	6.1×10^{-20}	.297
.1	.0043	6.1×10^{-20}	.294
.1	.0018	3.4×10^{-19}	.291
.1 to .01	Very little.	Solution saturated with FeS and H_2S.	.269
Trace.	Trace.	Solution saturated with FeS and H_2S.	.261
Trace.	Trace.	Excess of NaHS.	.120

The above conditions indicated by the table, some sulphur being held in suspension, approach those which are favorable to the development of marcasite.[3] In the last measurements the acidity was reduced by repeated additions of sodium hydroxide, so that the solution was plainly saturated with ferrous sulphide and with hydrogen sulphide. It was impossible to tell whether or not marcasite was forming on the electrode, which in the acid solution retained its characteristic steel-gray appearance, but in the neutral solution was somewhat blackened by adhering particles of ferrous sulphide.

[1] Knox, J., Zur Kenntniss der Ionenbildung des Schwefels und der Komplexionen des Quecksilbers: Zeitschr. Elektrochemie, vol. 12, p. 477, 1906.

[2] Drucker, K., Das Dissociationsschema der Schwefelsäure: Zeitschr. Elektrochemie, vol. 17, p. 398, 1911.

[3] Allen, E. T., Crenshaw, J. L., and Johnston, J., Mineral sulphides of iron: Am. Jour. Sci., 4th ser., vol. 33, p. 179, 1912.

The above results bring out the interesting fact that if the solution contains an excess of soluble sulphide a variation in the concentration of ferrous salt does not affect the potential, but if the concentration of the sulphide is at a minimum higher potentials may be obtained by adding ferric salt, the potential being then determined by the ratio of ferrous to ferric salt.

PYRRHOTITE.

The pyrrhotite used was collected at Ducktown, Tenn., by F. B. Laney, of the United States Geological Survey. Salt solutions and acids were found to impart a lower potential to pyrrhotite than to pyrite or marcasite. Commercial ferrous sulphide gave a much lower value than pyrrhotite, but it contains metallic iron. According to Richards and Behr,[1] metallic iron has a potential of −0.17 volt in normal ferrous sulphate.

The following readings were made with electrodes of pyrrhotite:

Potential of pyrrhotite.

	Volt.
In normal KCl, 0.54, 0.58, mean	0.56
Normal KCl, 0.001 normal NaOH	.45
0.99 normal KCl, 0.01 normal NaOH	.34
0.90 normal KCl, 0.1 normal NaOH	.25

A tenfold change in the quantity of sodium hydroxide in solution produces greater variation in the potential of pyrrhotite than in that of pyrite or marcasite, possibly because free sulphur is easily dissolved from the pyrrhotite by the sodium hydroxide, the result being a low "sulphide" potential. Normal sodium hydroxide gave a very inconstant value with pyrrhotite and appeared to convert it into oxide and soluble sulphide, but normal acid and normal sodium sulphide eventually gave much more constant values.

MAGNETITE.

The magnetite examined was in the form of large crystals from Mineville, Essex County, N. Y. (U. S. National Museum No. 47830). These crystals were but very slightly fractured. The potentials shown by different crystals in the same solution were rather discordant, although each single potential was very definite. Electrodes of magnetite are very easily polarized and respond quickly to changes in acidity and alkalinity of the solution. Briefly, the mineral behaves very much like an unattackable electrode, but lack of time has so far prevented a sufficiently detailed study to determine whether or not its potential can be correlated with the concentrations of its solution products. The following preliminary values—the

[1] Richards, T. W., and Behr, G. E., The electromotive force of iron under varying conditions and the effect of occluded hydrogen: Carnegie Inst. Washington Pub. 61, 1907.

averages measured with three different crystals—were obtained in the ordinary way, in the presence of air:

Potential of magnetite.

	Volt.
Normal KCl, with access of air	0.68
0.001 normal NaOH, 0.99 normal KCl	.65
0.01 normal NaOH, 0.99 normal KCl	.62
0.1 normal NaOH, 0.90 normal KCl	.56
0.1 normal H_2SO_4, 0.90 normal KCl	.86

When air is excluded magnetite in contact with water only eventually gives much lower values than those tabulated above. Thus, one specimen mounted in paraffin (fig. 6, p. 38) gave 0.55 volt after 22 days and eventually 0.46 volt.

GALENA.

Preliminary measurements on galena showed that various solutions alter its potential greatly. Acids do not yield as high values with galena as with pyrolusite, pyrite, or magnetite. In fact, changes in acidity give irregular results, for reasons which will be stated farther on. The potential is not very sensitive to a change in content of lead salt, but is sensitive to changes in alkalinity or concentration of sulphide.

A specimen that gave +0.49 volt in normal potassium chloride fell to 0.24 when hydrogen sulphide was passed into the solution, but rose again to 0.47 after being washed with water and replaced in potassium chloride. The addition of a trace of lead salt gave 0.48 volt.

The effect of excluding air was studied with galena as with pyrite, and it was found that in tenth-normal sulphuric acid the displacement of air by hydrogen resulted in no appreciable change in potential. The most plausible explanation of this fact is that the acid maintains a certain concentration of hydrogen sulphide, which determines the potential both in air and in hydrogen. With pyrite the acid generates so little hydrogen sulphide, if any, that air causes some oxidation of the ferrous salt to ferric. With galena hydrogen sulphide is certainly produced, even in air, so that no further effect of hydrogen would be expected. In an alkaline solution, on the other hand, a difference in potential was noted in the presence and in the absence of air. The value in tenth-normal sodium hydroxide in the presence of air was 0.27 volt and in hydrogen 0.12. The latter value is practically identical with that shown by pyrite under the same conditions, 0.13. Evidently these values are determined by a certain concentration of sulphide, as hydrogen in a platinum electrode gave −0.48 volt.

In normal potassium chloride in the presence of air galena gives a lower value than pyrite. The values obtained with different specimens at different times were as follows: +0.49, 0.38, 0.53, 0.58, 0.49, mean +0.49 volt. Pyrite gave 0.63 volt. When mounted in paraffin (fig. 6, p. 38) so as to exclude air, and in contact with water only, galena gave a potential slightly lower than in air, +0.46 volt, which remained fairly constant over a long period.

Bernfeld gives the following potential measurements for artificial lead sulphide electrodes:

Potential of artificial lead sulphide (Bernfeld).

	Volt.
Normal Na_2S, with some $Pb(C_2H_3O_2)_2$	−0.181 to −0.217
0.5 normal Na_2S, with some $Pb(C_2H_3O_2)_2$	− .172 to − .188
NaSH, H_2S introduced	− .0069 to − .0070
Normal Na_2S	− .196
0.5 normal Na_2S	− .179
0.25 normal Na_2S	− .160
0.125 normal Na_2S	− .140
0.0625 normal Na_2S	− .114
0 0312 normal Na_2S	− .096
0 0156 normal Na_2S	.076
Normal NaSH	− .0069
0.1 normal NaSH	− .0521
0.01 normal NaSH	− .1070

These results are in essential agreement with those shown by natural galena, ranging from −0.19 to −0.24 volt in normal Na_2S and −0.03 volt in normal NaSH. The potentials 0.49 volt in potassium chloride with air present or 0.46 volt in water with air excluded appear to be the most characteristic potentials of galena that I have noted, as I have found that potentials in sulphide solutions depend very much on the way the solutions are prepared.

The above results with galena indicate that a variation in the concentration of the lead salt has very little effect on the potential. The latter is greatly affected, however, by the concentration of sulphide. As a matter of fact, galena appears to maintain a fairly constant concentration of sulphide ion on its immediate surface, yielding in salt solutions a potential of 0.49 volt. In the presence of air galena therefore naturally functions as anode against pyrite. In the absence of air its potential may be brought down to low values by soluble sulphides, being then a "sulphide" potential.

Knox[1] measured the potential of a lead electrode in 0.1 molal Na_2S. As a mean of seven determinations of the combination

$$+Hg\ /\ Hg_2Cl_2,\ \text{normal KCl}\ /\ \text{normal KCl}\ /\ 0.1\ \text{molal}\ Na_2S\ /\ Pb$$

[1] Knox, Joseph, A study of the sulphid anion and complex sulphid anions. Faraday Soc. Trans., vol. 4, p. 48, 1908.

he obtained 0.773. Allowing a diffusion potential of 0.010 volt, which is probably better than making no correction at all, we have

$$Pb \;/\; 0.1 \text{ molal } Na_2S = -0.223$$

Inserting this value in the equation

$$E = 0.129 + 0.0295 \log C_{Pb^{++}}$$

and solving for C, we find, for Pb^{++}

$$C = 1.2 \times 10^{-12}$$

Following Knox and taking the concentration of S^{--} in 0.1 molal Na_2S to be 1×10^{-3}, we have the solubility product $[Pb^{++}][S^{--}] = 1.2 \times 10^{-15}$ and the concentration of Pb^{++} or S^{--} in a saturated aqueous solution of PbS at $25° = 3.4 \times 10^{-8}$ gm. ion per liter and the solubility of PbS in water at 25°, assuming complete dissociation, would be $= 3.4 \times 10^{-8}$ gm.-mole per liter.

SILVER SULPHIDE.

Bernfeld gives the following potential measurements for silver sulphide, H_2S having been introduced:

	Volt.
Normal NaSH	−0. 178
0.1 normal NaSH	− . 123
0.01 normal NaSH	− . 069

Knox measured the potential of a silver electrode in 0.1 molal Na_2S. For the combination

$$+Hg \;/\; Hg_2Cl_2, \text{ normal KCl} \;/\; \text{normal KCl} \;/\; 0.1 \text{ molal } Na_2S \;/\; Ag-$$

he obtained the value 0.880. Allowing 0.010 volt for the diffusion potential, as above, we have, for the single potential, the value

$$Ag \;/\; 0.1 \text{ molal } Na_2S - 0.330$$

Substituting in the equation

$$E = 1.06 + 0.059 \log C^{\;\;+}$$

we have $C = 4.3 \times 10^{-24}$ for Ag^+. The solubility product of Ag_2S is therefore

$$(4.3 \times 10^{-24})^2 \; (1 \times 10^{-3}) = 1.8 \times 10^{-50}$$

and in a saturated aqueous solution of Ag_2S we should have $Ag^+ = 3.3 \times 10^{-17}$; or, assuming complete dissociation, the solubility of Ag_2S would be 1.6×10^{-17} mole per liter at 25°.

BISMUTH SULPHIDE.

Bernfeld gives the following potential measurements for bismuth trisulphide:

	Volt.
Normal NaSH + some antimony solution	+0. 017
0.1 normal	+ . 073
0.01 normal	+ . 133

MERCURIC SULPHIDE.

Behrend gives two measurements on mercuric sulphide,[1] namely, for mercury in tenth-normal NaSH, −0.12, and in tenth-normal Na_2S, −0.28, the solution being saturated with the sulphide of mercury. These values are very close to those that I obtained from the soluble sulphides with a smooth platinum electrode, as described on page 47.

NICKEL AND OTHER SULPHIDES.

The potentials of several metals in solutions saturated with their sulphides were measured by Zengelis.[2] It is difficult to determine from his published results the correct sign or even the values of some of the single potentials, but the values stated in the following table are believed to be correct:

Single potentials of metals in solutions saturated with their sulphides, as determined by Zengelis.

	Volt.
Nickel in NiS	−0.02
Silver in Ag_2S	− .34
Cobalt in CoS	− .04
Lead in PbS	+0.20 to + .06
Copper in CuS	− .085
Copper in Cu_2S	− .203

ELECTROMOTIVE BEHAVIOR OF SOLUBLE SULPHIDES.

REDUCING POWER OF SOLUBLE SULPHIDES.

One of the most characteristic properties of soluble sulphides, aside from their ability to form insoluble precipitates with many metals, is their reducing power. This is shown in the familiar reactions with ferric salts, chromates, ferricyanides, the halogens, the nitro group, nitric acid, and even sulphuric acid. If we consider this property essentially a property of sulphide ions, the reduction of a ferric salt, for example, may be indicated by the equation

$$2Fe^{+++} + S^{--} = 2Fe^{++} + S$$

According to this equation the sulphide ions give up their negative charges while an equal number of positive charges are neutralized; free sulphur remains; no other ions appear to be directly concerned with the reducing action. The tendency of sulphide ions to give up their charges may also be shown by the production of an electric current as illustrated by the experiments on page 13. The single

[1] Behrend, R., Elektrometrische Analyse: Zeitschr. physikal. Chemie, vol. 11, p. 481, 1893.
[2] Zengelis, K., Ueber die elektromotorische Kräfte unlöslicher und komplexer Salze: Idem, vol. 12, pp. 298–313, 1893.

For the secondary ionization Knox gives

$$K_2 = \frac{[H^+]\,[S^{--}]}{[SH^-]} = 1.2 \times 10^{-15} \ldots\ldots\ldots\ldots\ldots \text{(II)}$$

whence by combining (I) and (II) we have

$$[S^{--}] = \frac{1.1 \times 10^{-23}}{[H^+]^2}$$

an expression giving the sulphide ion concentration for any solution of known hydrogen ion concentration. In this way the sulphide ion concentrations of the next table were obtained and from them values of E_0 calculated by equation (1).

Sulphide potentials observed and calculated by equation (1).

Solution (concentration per liter).	Sulphide ion concentration.	E observed (volt).	E^0 calculated (volt).
1 mole $HCl + H_2S$	1.1×10^{-23}	+0.40	−0.27
1 mole acetic acid $+ H_2S$	$.6 \times 10^{-[illegible]}$	+.29	−.24
1 mole $KCl + H_2S$	$1.2 \times 10^{-[illegible]}$	+.20	−.25
1 mole NaSH	$3.6 \times 10^{-[illegible]}$	−.14	−.27
1 mole Na_2S	.09	−.27	−.30

There is a fair approach to constancy in the values of E_0, the mean value being −0.26, so that equation (1) must have some significance in view of the enormous range of the sulphide ion concentration and would appear to be applicable to the determination of sulphide ion concentrations provided polysulphides are absent. The relations shown, however, can not be regarded as a final solution of the problem for NaSH and Na_2S, as will appear from what follows.

PREPARATION OF SODIUM HYDROSULPHIDE.

In preparing sodium hydrosulphide the best substance with which to start is sodium, as recommended by Küster and Heberlein,[1] but for many purposes sodium hydroxide suffices. If it is desired to avoid oxidized products it is advisable to pass a current of hydrogen through the sodium hydroxide before introducing hydrogen sulphide, and at the same time to have a piece of platinized platinum in the bottle to make the hydrogen more effective through electrolytic action. The saturation of sodium hydroxide with hydrogen sulphide yields a solution containing an excess of hydrogen sulphide. Part of this excess may be removed from a solution as concentrated as

[1] Küster, F. W., and Heberlein, E., Beiträge zur Kenntniss der Polysulfide: Zeitschr. anorg. Chemie, vol. 43, p. 55, 1905.

normal by bubbling a stream of hydrogen through the solution for some hours. The changes in the solution from the first introduction of H_2S to supersaturation and expulsion of the excess may be followed with advantage by potential measurements. The results of one experiment in which the excess of H_2S was neutralized by adding NaOH from a burette were as follows:

Effect of neutralizing excess H_2S in normal NaSH with NaOH.

4 normal NaOH added.	Potential of cell.	Remarks.
Cc.	*Volt.*	
0.5	0.605	H_2S in excess.
1.0	.612	
1.5	.635	Solution becomes alkaline to phenolphthalein.
2.0	.700	Solution practically NaSH.
2.5	.785	
3.0	.794	
3.5	.797	
4.0	.798	About 16 per cent of NaSH now converted into Na_2S.

It will be observed that the potential changes vary rapidly when the solution has a composition near to NaSH. The value 0.70 for the cell, or the single potential -0.14, has been selected as the first approximation to the correct potential for a normal solution of the composition NaSH. Such a solution is plainly appreciably hydrolyzed, as is shown by the fact that the solution already becomes alkaline to phenolphthalein at a potential which clearly corresponds to an excess of H_2S. The above measurements also afford a very clear explanation of the many discrepancies that have been noted in the data of observers working with solutions of NaSH; evidently the acidity has not been definitely regulated.

CHEMISTRY OF THE SULPHIDE ELECTRODE.

It has been stated that in developing a current the sulphide ions probably give up their charges, leaving free sulphur. This appears to be the primary action. When a feeble current (0.1 milliampere) was passed into a solution of hydrogen sulphide through a platinum anode a white cloud of sulphur was formed on the platinum and in the solution near the platinum; when sodium hydrosulphide or sodium sulphide was employed, however, sulphur was not a visible product nor was any gas evolved, but after a time the solution turned yellow, indicating the formation of a polysulphide. The formation of a polysulphide may be considered a secondary effect due to the solution of sulphur freed by the current in the sodium sulphide present, or it

may be that polysulphide ions are an oxidation product of sulphide ions, a possibility that will be considered presently.

The pure sulphide electrode appears to be irreversible. When a current is passed in the direction to make the platinum a cathode hydrogen is set free. The likelihood that this hydrogen will not give a proper potential with a smooth electrode has been pointed out. In fact Bose long ago concluded that the saturation of even platinized electrodes is an extraordinarily slow process of diffusion of the gas into the electrode material. There appeared to be no difficulty, however, in attaining the sulphide potential from either side by the compensation method.

To gain light on the action of the reversed current experiments were made to see whether free sulphur in contact with platinum could under any conditions be made to ionize. A solution of sulphur in carbon disulphide was allowed to evaporate from the surface of a platinum electrode, and the electrode, thus coated with numerous crystals of sulphur, was allowed to stand in normal potassium chloride in a closed half cell for a long period. The potentials observed are stated in the first part of the table below:

Potential of platinum coated with sulphur.

Solution.	Time.	Cell.	Potential of platinum.
KCl	Start	(Hg−) 0.10	+0.66
	1 hour	.05	.61
	2 days	(Hg+) .03	.53
	5 days	.06	.50
	12 days	.11	.45
NaOH	Start	.28	.28
	1 day	.24	.32
	2 days	.44	.12

It seems that the sulphur may be in part the cause of the observed slow fall in potential, but there are so many uncertainties about the behavior of a piece of platinum in a neutral solution that the results are of questionable significance. They show, however, that the effect, if there is one, is produced very slowly at ordinary temperature.

It is well known that sulphur dissolves in alkali hydroxides at an appreciable speed.[1] It is not surprising, therefore, that a piece of platinum coated with sulphur as described above and immersed in sodium hydroxide gave a lower potential more quickly, as is shown in the second part of the table above. Of course the production of a soluble sulphide in this way may be regarded as an action that is wholly "chemical" and the electromotive effect as secondary. The experiments are therefore inconclusive as to whether the platinum assisted the ionization of the sulphur at all.

[1] Küster and Heberlein, op. cit., p. 80.

BEHAVIOR OF POLYSULPHIDES.

The electromotive action of polysulphides is important because they appear to be formed by the electrolytic oxidation of alkali sulphides as well as by the action of sulphur on those salts. Moreover, they may be reduced electrolytically. There appears to be a possibility of arriving at a reversible electrode here. Are polysulphide ions the first direct oxidation product of sulphide ions, rather than sulphur, and are they capable of affecting the electromotive behavior of the sulphide ions?

Küster[1] measured the potential of several solutions containing polysulphides, and his data are reproduced for reference in the accompanying tables:

Küster's data on polysulphides.

[Cell: Pt / Na_2S_x / normal KCl / HgCl / Hg+.]

Solutions saturated with sulphur.

Formal concentration of Na_2S_x (saturated with S).	x in Na_2S_x.	Potential of cell.
2	4.47	0.621
1	4.67	.609
0.5	4.84	.600
.25	4.98	.592
.125	5.12	.584
.062	5.22	.576
.031	5.24	.568
.0155	5.20	.560
.0077	5.04	.552
.0038	4.45	.541

Solutions with varying sulphur content.

Composition of solution (half formal).	Potential of cell.
$Na_2S_{1.00}$	0.799
$Na_2S_{1.25}$	.787
$Na_2S_{1.50}$	.766
$Na_2S_{2.00}$	.750
$Na_2S_{3.00}$	.731
$Na_2S_{4.00}$	.677
$Na_2S_{4.84}$	.600

Küster's data were supplemented by measurements of the effect of dilution, given under the next heading.

EFFECT OF DILUTION.

A few measurements were made on solutions of Na_2S. The potentials obtained reached constancy very slowly. Solutions containing

[1] Küster, F. W., Beiträge zur Kenntniss der Polysulfide: Zeitschr. anorg. Chemie, vol. 44, pp. 439, 445.

some polysulphide gave more easily reproducible values, and measurements of such solutions are shown in the accompanying table:

Effect of dilution on potential of cell.

Formal concentration.	Na_2S.	Na_2S_2.	Na_2S_3.	Na_2S_4.
2	0.851	(0.785)	....	....
1	.828	.768	0.748	0.696
0.5	.803	.752	.731	.683
.25	.783	.734	.716	.671
.125	.760	.718	.700	.658
.062	....	.700	.683	.647
.031	....	.682	.667	.634
.015	....	(.665)	(.650)	(.622)

Apparently the more polysulphide there is present the less marked is the effect of dilution. But the potential of a solution of even the composition $Na_2S_{4.7}$ varies somewhat with dilution, and at about 0.015 formal the solution decomposes, with separation of sulphur.

The potential of pure Na_2S appears to change by about 0.07 for a tenfold dilution, which is not at once reconcilable with equation (1) (p. 47); that of Na_2S_4 about two-thirds as much. Extrapolating, it would seem that it would require a solution of rather high sulphur content, possibly as high as Na_2S_6, to have a constant potential independent of the dilution. Such a solution can not, however, be prepared.

If we try to resolve such a solution into two components it appears that the simpler one might be as complex as Na_2S_4, which would make the higher one Na_2S_8. The other possible components would be equal amounts of Na_2S_3 and Na_2S_9, or of Na_2S_2 and Na_2S_{10}, or of Na_2S and Na_2S_{11}, or, lastly, different amounts of two or all of these species. The properties of the higher polysulphides are such, however, that the assumption of much of the species Na_2S in them appears unreasonable.

We can gain some light on this perplexing situation by considering the changes in potential when the composition of the solution is varied from Na_2S to Na_2S_x. Measurements were made with this point in view, and some of the results are given in the following table.

In seeking a mathematical elucidation of the results let us, following custom, see if the potential can be expressed as a function of any two molecular species. For the sake of simplicity let us assume that the first oxidation product is disulphide, according to the reaction—

$$2S^{--} = (S_2)^{--} + 2\ominus$$

We should then have a relation for the oxidation-reduction potential like—

$$E = E_0 + \frac{.059}{2} \log \frac{[S^{--}]^2}{[(S_2)^{--}]} \text{-----------------} \quad (2)$$

In testing this equation it is only necessary to resolve solutions of compositions between Na_2S and Na_2S_2 into the proper mixtures of the two species as shown in the table below and assume that the ionic concentrations are proportional to the molal.

Potential of cell calculated by equation (2).

[Pt / 1.0 molal Na_2S_x / 1.0 normal KCl / HgCl / Hg+.]

Composition x in Na_2S_x.	Formal concentration of—		Potential observed.	E_0 calculated by (2).
	Na_2S.	Na_2S_2.		
1.00	1.00	0.00	0.828	....
1.20	.80	.20	.800	0.782
1.40	.60	.40	.785	.786
1.60	.40	.60	.778	.795
1.80	.20	.80	.772	.810
2.00	.00	1.00	.768	....

As the above table shows, equation (2) does not yield a constant value of E_0. In fact, the shape of the potential curve suggests that the second species must be more complex than Na_2S_2. Apparently an excess of sulphur forms at once a higher polysulphide than Na_2S_2. The nearest approach to a uniform slope in the curve falls between Na_2S_2 and Na_2S_3, indicating that if Na_2S is one member the other is nearly as complex as Na_2S_4. The electric oxidation would then be

$$4S^{--} = (S_4)^{--} + 6\ominus$$

giving for the potential the expression—

$$E = E_0 + \frac{.059}{6} \log \frac{[S^{--}]^4}{[(S_4)^{--}]} \quad \text{(3)}$$

An evaluation of E_0 by this equation is shown in the next table:

Potentials calculated by equation (3).

Composition x in Na_2Sx.	Formal concentration of—		Potential observed.	E_0 calculated by (3).
	Na_2S.	Na_2S_4.		
1.50	0.83	0.17	0.780	0.778
1.75	.75	.25	.772	.770
2.00	.67	.33	.766	.768
2.25	.58	.42	.761	.767
2.50	.50	.50	.757	.766
2.75	.42	.58	.752	.765
3.00	.33	.67	.748	.765
3.25	.25	.75	.743	.765
3.50	.17	.83	.735	.764

It will be seen on referring to the table that equation (3) gives a fairly constant value of E_0 from Na_2S_2 to Na_2S_3. No equation as complicated as this has to my knowledge been applied to potential meas-

urements before, although Fredenhagen suggested such equations.[1] An equation corresponding to the intermediate possibility, namely,

$$3S^{--} = (S_3)^{--} + 4\ominus$$

was found less satisfactory than equation (3).

There is one other possibility—that of writing NaS instead of Na_2S_2 for the "disulphide," giving the reaction—

$$S^{--} = S^{-} + \ominus$$

The mathematical test of this possibility showed that it does not fit the facts, except incidentally, for compositions near $Na_2S_{1.3}$.

CONCLUSIONS.

The conclusions from the preceding discussion are then as follows: The electromotive behavior of the polysulphides resembles in a general way that of other reversible oxidation-reduction potentials involving anions. Although it is impossible to account for the behavior without assuming that several species are present in a rather complicated equilibrium, it appears unnecessary to consider Na_2S_2 one of them or possibly even Na_2S_3. The potentials may be calculated as if they depended on the relative concentrations of the two species Na_2S and Na_2S_4 for the range from Na_2S_2 to Na_2S_3. On reaching a composition near Na_2S_4 a rapid shift to a much higher sulphide is suggested.

If polysulphides are absent equation (1) on page 47 is somewhat applicable; if they are present equation (3) appears most applicable. Future investigation must discover an expression which will fit the facts for all possible combinations. For acid solutions, however, equation (1) is satisfactory over wide ranges of sulphide ion concentration.

The investigation of the behavior of soluble sulphides has proved very instructive with regard to that of the insoluble sulphides if one can assume that the potentials noted with the insoluble sulphides are due to certain concentrations of sulphide ions or polysulphide ions. For example, the potential of pyrite would certainly be expected to correspond to that of a polysulphide, and its electromotive behavior is entirely consistent with that view, since it gives a higher potential than the monosulphide minerals.

CORRELATION OF THE MEASUREMENTS OF POTENTIAL.

The study of the potential of various combinations of solutions and minerals has so far merely opened up a large number of new problems, whose complete elucidation will require further study.

[1] Fredenhagen, C., Zur Theorie der Oxydations- und Reductionsketten: Zeitschr. anorg. Chemie, vol. 29, p. 446, 1902.

Enough has been done, however, to establish the position of several minerals in the electromotive scale. It has been shown that oxidizing, reducing, acid, and alkaline solutions in contact with minerals impart widely varying potentials to the minerals. Neutral salts, however, have less effect and it seems reasonable to conclude that the potentials shown in neutral salt solutions which are not markedly oxidizing or reducing are practically identical with the potentials that the minerals would assume in pure water—that is, they are due to the solution products of the minerals. The chief sources of error in obtaining such potentials are: The presence of impurities in the minute fractures and pores of the minerals; the fact that the atmospheric environment is not, in general, in equilibrium with the minerals and their solution products; and the extreme slowness with which the very insoluble minerals attain equilibrium with solutions in contact with them.

It is obvious that the ions formed by the solution of most minerals in water fall into the class of easily oxidizable or reducible substances. The mineral potentials are therefore "oxidation and reduction potentials." In order to present a general view of the results of all possible combinations in cells of different types so that the values may be compared, it will be advantageous to assemble in one table the available data showing single potentials. Such a table has been prepared and is presented on page 56, all potentials being stated on the assumption that the normal calomel electrode has a potential of 0.56 volt. The concentrations are normal unless otherwise stated, except that several values for oxidizing and reducing solutions are taken from Bancroft's data, in which the concentrations were about one-fifth normal. An attempt will be made to apply this table to elucidate combinations found in nature.

The table on page 56 shows the oxidizing or reducing potentials of a number of solutions, as well as the positions of solid conductors in the series when these conductors supply their own solution products. It will be noted that the sulphides cover a relatively narrow range, so narrow, in fact, that the potentials which metallic copper might show in solutions of different concentration of copper sulphate would embrace nearly the whole range. It is this fact, coupled with their great insolubility and the slow rate at which they attain equilibrium, that has made an exact determination of the positions of the minerals difficult. The possible usefulness of a new method of presentation, aiming to indicate the direction in which certain chemical reactions will proceed, is the main justification of the table. I am well aware that future study may alter the positions of the minerals slightly if it shall prove possible to refer their electromotive behavior to reversible equilibria. Nevertheless the table shows a natural association

between certain solutions and minerals, whether one regards the solutions as produced from the minerals or the minerals as produced from the solutions. The principal qualification necessary is the great effect of varying concentration, which can not easily be shown by such a table as that given below. For example, soluble sulphides may impart potentials anywhere from −0.30 to +0.60, according to their concentration.

Single potentials of solutions and solid electrodes.

Solution (unattackable electrode).[a]	Potential.	Solid conductor (in water or solution stated).	Potential.
	Volts.		*Volts.*
Gold solution (aurous) [b]	+1.8	Lead dioxide in 0.5 normal sulphuric acid.[c]	+1.84
Sulphuric acid saturated with oxygen	+1.47	Manganese dioxide in sulphuric acid	+1.72
Platinum solution (platinous) [d]	+1.14		
Acid ferric sulphate	+1.11	Pyrolusite in water	+1.11
Oxygen in water [e]	+1.09		
Sulphuric acid	+1.07		
Silver solution	+1.06		
Mercury solution (mercurous) [d]	+1.03		
		Manganite in water	+ .96
Thousandth-normal sulphuric acid	+ .95		
Acidified ferrous sulphate [f]	+ .79		
Antimony solution [d]	+ .74	Magnetite in water	+ .68
Pure water [e]	+ .68		
Neutral ferrous sulphate	+ .63	Marcasite in water	+ .62
Sodium sulphite [f]	+ .58	Pyrite in water	+ .60
Cuprous chloride [f]	+ .56	Pyrrhotite in water	+ .56
Potassium arsenite [f]	+ .51	Galena in water	+ .46
Acidified stannous chloride	+ .50	Copper [g]	+ .44
Thousandth-normal sodium hydroxide	+ .41		
Sodium hydroxide	+ .29		
Sodium hydrosulphide	− .14	Lead [g]	− .04
		Nickel [g]	− .12
Hydrogen in water [e]	− .14		
Sodium sulphide	− .27		
Alkaline stannous chloride	− .30	Cadmium [g]	− .31
		Iron [h]	− .32
Hydrogen in sodium hydroxide	− .51	Zinc [g]	− .66
		Manganese [g]	− .97

[a] Under certain conditions minerals may function as unattackable electrodes for many of these solutions, but for hydrogen and oxygen platinized electrodes are essential.

[b] Abegg, Handbuch der anorganischen Chemie, vol. 2, pt. 1, pp. 674, 788, 1908.

[c] Tower, O. F., Studien über Superoxyd-Elektroden: Zeitschr. physikal. Chemie, vol. 18, pp. 17–50, 1895.

[d] Wilsmore, N. T., Ueber Elektroden-Potentiale: Idem, vol. 35, p. 318, 1900. Solution normal with respect to metallic ion.

[e] Calculated as shown on a succeeding page.

[f] Bancroft, recalculated by Neumann, Ueber das Potential des Wasserstoff und einiger Metalle: Zeitschr. physikal. Chemie, vol. 14, p. 228, 1894.

[g] The value stated is the "electrolytic potential" (Wilsmore) minus (6×0.029), corresponding to a supposed solution of a millionth normal ionic concentration.

[h] Richards, T. W., and Behr, G. E., The electromotive force of iron under varying conditions and the effect of occluded hydrogen: Carnegie Inst. Washington Pub. 61, 1907. The value stated is that of Richards and Behr, −0.15 volt against normal ferrous sulphate, reduced by (6×0.029), as for the other metals.

It is well known that certain oxidation-reduction potentials depend on the ratio of the concentrations of two ions of higher and lower valence concerned.[1] But if a single pure reagent is taken in water an adjustment immediately occurs with the other ions present, fixing a concentration of the second member, so that as a rule the potentials of single reagents have a perfectly definite meaning. For

[1] See Peters, R., Ueber Oxydations- und Reductionsketten: Zeitschr. physikal. Chemie, vol. 26, p. 201, 1898.

example, such reactions with ferric and ferrous salts may be represented as follows:

$$4Fe^{+++} + 4HO^{-} = 4Fe^{++} + O_2 + 2H_2O$$
$$2Fe^{++} + 2H^{+} = 2Fe^{+++} + H_2$$

Theoretically these reactions must occur and modify the character of the water, although the modification of the water is usually neglected.[1] Except for this action the potentials of solutions of single pure salts are not reversible. The oxidizing and reducing solutions are perfectly available, however, for furnishing current in one direction, and the potentials thus manifested by solutions of single salts are shown by the table. In view of the above facts all oxidation and reduction potentials might be regarded as due to certain concentrations of oxygen and hydrogen. Such concentrations would of course usually be less than those of saturated solutions; moreover, platinized electrodes are necessary to secure a proper electric action of oxygen and hydrogen, whereas, fortunately, the salts may enter into electromotive action directly.

A very interesting distinction has been brought to light as a result of the study of mineral electrodes. The solution products of many minerals in water are so dilute that their potentials, even with an "unattackable electrode," would correspond to very small concentrations of oxygen or hydrogen. This fact led to the thought that water itself, in the presence of platinum, may be assumed to have certain concentrations of free oxygen and hydrogen in equilibrium with it, and that it would be interesting to calculate the potential which would be shown by hydrogen or oxygen electrodes, with the gases at the pressures possible in pure water. With an ideal inert conductor the hydrogen or oxygen might not need to be at atmospheric pressure in order to establish a definite potential. Such an electrode in pure water should have the potential 0.676 volt. This is calculated as follows:

Lewis[2] has shown that the electrode [normal OH^-, O_2] has the value $+0.674$ volt at 25° C., and according to Wilsmore the electrode [normal H^+, H_2] has the value $+0.277$ volt. We may calculate the potentials which would be obtained in pure water in which the hydrogen and hydroxyl ions have the concentration 1.05×10^{-7} by the following equations:

$$E_{O_2} = 0.674 + 0.059 \log \frac{1}{1.05 \times 10^{-7}}$$

$$E_{H_2} = 0.277 - 0.059 \log \frac{1}{1.05 \times 10^{-7}}$$

[1] A similar modification of water by silver and copper was established by F. Fischer (Zeitschr. physikal. Chemie, vol. 52, p. 55, 1905).

[2] Lewis, G. N., The potential of the oxygen electrode: Am. Chem. Soc. Jour., vol. 28, p. 170, 1906.

This would give +1.087 volt for [water, O_2] and −0.136 volt for [water, H_2] both gases being at atmospheric pressure.

In figure 7 the two single potentials 1.087 and −0.136 are indicated by the points *A* and *C*. We may now calculate the potentials of oxygen and hydrogen electrodes at partial pressures less than one atmosphere by the following equations:

$$E_{O_2} = 1.087 - \frac{0.0592}{4} \log \frac{1}{P_{O_2}}$$

$$E_{H_2} = 0.136 + \frac{0.0592}{2} \log \frac{1}{P_{H_2}}$$

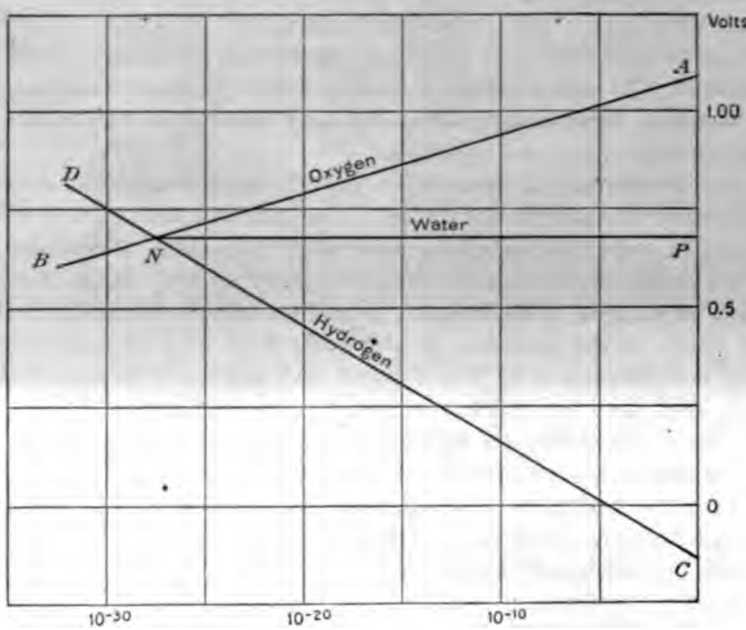


FIGURE 7.—Single potentials of oxygen and hydrogen electrodes in water.

If the oxygen is at a lower partial pressure than atmospheric, the potential will be reduced by 0.0148 volt for every tenfold decrease in pressure. This decrease is shown by the line *AB*. With a tenfold decrease in partial pressure the hydrogen potential rises 0.0296 volt, as shown by the line *CD*. At the point *N* both gases would have the same pressure and the potential, indicated by *P*, would be 0.679 volt.

The potential *P* is not exactly the potential which we are seeking, since in the purest water conceivable the partial pressure of the hydrogen will be twice that of the oxygen, on account of the dissociation of water into hydrogen and oxygen according to the equation

$$2H_2O = 2H_2 + O_2$$

It is true that the concentrations of hydrogen and oxygen in water are extremely small, but they appear to be related to the oxidizing and reducing power of solutions. The correction on account of the slight difference in the partial pressures of oxygen and hydrogen at pressures so low would reduce the above potential only three or four thousandths of a volt and is therefore almost negligible when compared with the other possible uncertainties in the value. The final corrected potential sought is 0.676 referred to the normal calomel electrode.

If one could imagine an electrode of oxygen at a lower pressure than that corresponding to the point N, it would have a lower potential than a hydrogen electrode at the same pressure, and under such conditions water would decompose spontaneously. This decomposition could in fact occur until the partial pressure of the hydrogen became twice that of the oxygen, but no longer, a fact that shows the reasonableness of considering a platinum electrode in a neutral solution at a lower potential than 0.676 a hydrogen electrode, following the line NC instead of NB. A lower potential in a neutral solution must correspond to an excess of hydrogen.

Preuner[1] has calculated the equilibrium constant of the reaction $2H_2+O_2=2H_2O$ at 20°, finding

$$\frac{(H_2)^2\,(O_2)}{(H_2O)^2}=5.7\times10^{-78}$$

This becomes 1.6×10^{-76} at 25°, at which temperature the vapor pressure of water is 0.0031 atmosphere, so that in the presence of liquid water we have

$$\frac{(H_2)^2\,(O_2)}{(0.0031)^2}=1.6\times10^{-76}$$

or

$$(H_2)^2\,(O_2)=1.5\times10^{-81}$$

Now in pure water there will still be two volumes of free hydrogen for every volume of free oxygen, so that we may write

$$[2(O_2)]^2\,(O_2)=1.5\times10^{-81}$$

whence

$$(O_2)=7.2\times10^{-28}$$

and

$$(H_2)=1.4\times10^{-27}$$

the last two values being the partial pressures of oxygen and hydrogen in pure water.

It is a surprising fact that at the partial pressures of oxygen and hydrogen thus calculated the potentials of the two electrodes would be

[1] Preuner, G., Ueber die Dissociationskonstante des Wassers und die elektromotorische Kraft des Knallgaskette: Zeitschr. physikal. Chemie, vol. 42, p. 54, 1903.

0.670 and 0.688, if the calculation is made as usual from the values 1.087 and −0.136 for the two electrodes in water and at atmospheric pressure, with a mean value 0.679 volt.

We now have two values for the potential sought.

From Lewis's and Wilsmore's values when $E_{O_2} = E_{H_2}$ 0.676
From Preuner's data for p_{H_2} and p_{O_2} 0.679

For the present the value 0.676 volt will suffice.

Several interesting distinctions may be drawn in regard to this potential. Bearing in mind the fact that it refers to a neutral solution we obtain a criterion by which we may decide whether a solution contains an excess of oxygen or hydrogen over the amounts necessary to form water. Thus all neutral solutions imparting a higher potential than 0.676 to an unattackable electrode should contain an excess of free oxygen, whereas those giving a lower potential should contain an excess of free hydrogen. The various oxidizing and reducing solutions may contain almost every concentration of free oxygen and hydrogen. Thus waters at the surface of the earth will contain oxygen at a pressure of about one-fifth of an atmosphere. The oxygen in the ground water, however, will be considerably reduced, passing through very small concentrations until at a certain depth, differing according to the geologic structure, there will be practically no excess of oxygen or hydrogen. Below this depth hydrogen will be in excess at concentrations increasing with the depth. The differentiating potential 0.676 will be higher in acid solutions and lower in alkaline solutions, but it is most convenient to discuss its application in neutral solutions. It is a sort of natural zero of potential.

Salts of the metals more noble than copper will behave like oxidizing agents—that is, an indifferent electrode immersed in them will become a cathode with respect to the imaginary electrode of 0.676 volt. Combinations such as water / metal of the metals less noble than copper will act as reducing agents—that is, will function as anodes against the reference electrode. According to the same criterion the mineral sulphides would be feeble reducing agents, although their solution products are probably hydrolyzed slightly, yielding feebly alkaline solutions. Considering this fact they may indeed be said to lie very near the point where the solution contains no excess of oxygen or hydrogen.

The potential shown by an indifferent electrode in a given solution may be ascribed, then, to two factors, one of them a certain concentration of oxygen or hydrogen, the other a certain concentration of acid or alkali. A potential may be the resultant of many properties in a solution, such as acidity, oxidizing power, degree of ionization or hydrolysis, and the nature of the cations and anions present, but the potential can be interpreted only through the two factors just men-

tioned. The line of demarcation drawn above, 0.676 volt, applies only to neutral solutions, but every other solution would have a similarly characteristic potential which could easily be calculated and which would determine its oxidizing or reducing power. It is interesting to observe in this connection that, according to Bancroft's original measurements, neutral ferrous sulphate has a single potential of 0.63—that is, it is feebly reducing according to the above criterion of potential—whereas an acidified solution shows a potential of about 0.79, $NaHSO_3$ is given the value 0.66, and the next neutral oxidizing agent has a considerably higher value. In other words the potential 0.676 fits in very well as a dividing line between "oxidizing" and "reducing" solutions in Bancroft's data although the point of division can not be located exactly, as his measurements included acid and alkaline as well as neutral reagents.[1]

It is a general rule of wide application that if two reactions can occur simultaneously at the same electrode one will proceed until the potential of the other has been reached. A solution that tends to make an indifferent electrode a cathode combined with a solid that tends to function as anode in water will produce spontaneously a chemical reaction.

By keeping this rule in mind and considering the several possibilities in any given combination we may gain some idea of the nature of the reaction that will occur when a given mineral and solution are brought together. Consider, for example, a piece of iron and a solution of gold. The table on page 56 shows that a gold solution is an oxidizing solution (+1.8 volts) and tends to make any conductor a cathode. Iron (−0.32 volt), on the other hand, tends to function as anode. On bringing the two together the iron acts a moment as cathode until some gold is deposited, then as anode, gold being precipitated upon itself and iron going into solution. Since neither action alone is polarizable the combined action is not polarizable and practically all the gold will be precipitated at the expense of the iron.

Now take the combination of pyrite and an acidified ferric sulphate solution. Ferric sulphate solution tends to make any conductor a cathode with very little polarization. On the other hand, if pyrite is made anode in water it is easily polarized and its constituents are partly oxidized. The combined result of pyrite acting simultaneously as cathode and anode in ferric sulphate is that ferric sulphate is reduced to the extent required to polarize the pyrite anodically, a little of the pyrite thereby being oxidized. That this occurs is shown electrically by the electromotive force of the cell:

Platinum / acid ferric sulphate / water / pyrite

[1] Single potentials compiled from Bancroft's data by Neumann, Ueber das Potential des Wasserstoff und einiger Metalle: Zeitschr. physikal. Chemie, vol. 14, p. 228, 1894.

that is, by separating the reacting substances, for otherwise no current would be evident. Or it may be shown chemically as follows: If pyrite is placed in a very dilute solution of potassium ferricyanide at the right concentration a precipitate of Turnbull's blue will be formed slowly from ferrous salt dissolved from the pyrite and the ferricyanide. If, however, some acidified ferric sulphate solution is added the precipitate forms rapidly a thin adhering blue film on the pyrite. The explanation of this action is that the ferric sulphate is slightly reduced and the pyrite is oxidized, so that a reaction occurs in the boundary layer. It is possible to obtain such coatings quickly on many minerals by using solutions well separated from them in the potential series.

A combination of any pair of the solutions or conductors whose single potentials are given in the table on page 56 will constitute a cell that will yield an electric current on completing the circuit. Some of these cells will be very easily polarizable and others less so, as was shown in the earlier pages. An extended study of polarization would undoubtedly disclose interesting relations between rates of oxidation, diffusion, porosity, and other factors, but this study must be reserved for another time. The table plainly indicates, however, in general, the degree of compatibility of various solutions and minerals with each other; the nearer equal their potentials the greater will be the chance of compatibility.

APPLICATION TO ORE DEPOSITION.

GENERAL CONDITIONS.

It is evident from the preceding discussion that ore deposits are likely to be the seat of countless differences in electric potential between both ores and solutions, the whole system being instable and subject to continuous change. Geologic changes expose large areas to chemical attack. Chemical differences thus produced will generate electromotive forces, which, if opportunity is afforded, will produce currents operating to equalize the differences in potential. Diffusion in and through the solutions will also generate feeble electric currents and, conversely, electric currents may influence the diffusion and transference of matter. The greater electric conductivity of solutions as compared with conducting minerals will probably restrict the currents to solutions wherever two courses may be possible.

If a particle of ore without electric potential could be transferred in that condition to a solution it would at once assume an electric charge. Without attempting to explain this phenomenon, one may say that the particle of ore has become slightly polarized and will remain polarized until the system is reduced to electric uni-

formity by chemical action or until there is an addition or subtraction of electricity. While it is in the solution the ore will be protected somewhat from chemical attack or, on the other hand, it may be made more liable to attack, according as the polarization is positive or negative. If a current is generated a chemical change will occur either in the ore or in the solutions bathing the ore. It has been shown that when the current is in the direction "solution to ore" the chemical change is a "reduction." Conversely, a current from ore to solution must be accompanied by oxidation. Whatever may be the course of the current, secondary reactions may cause the precipitation of insoluble films on the minerals that form the electrodes.

It is conceivable that differences in degree of polarization might affect the growth or solution of minerals and thus lead to variation in crystal form, distortion, unequal development of the different faces, and like effects. The polarization need not be caused wholly by the solution immediately in contact with an ore; it might be the result of electric activity at another point, the current being transmitted through the conducting ore. Though crystallization and solution are affected by foreign salts in solution no attempt has been made, so far as I am aware, to correlate these effects with electric conditions, partly, no doubt, for the reason that the crystallization of electrically conducting minerals can not be studied under conditions as favorable as those available for the study of the crystallization of more soluble substances. If it is granted that different crystal faces have different solubilities this fact would demand as a corollary that there should be different degrees of electric polarization on the different faces.

Electric activity is most likely to come into play in ore deposits, however, when a single mineral or body of ore is bathed by different solutions at different places. The electric circuit afforded by such conditions would be like the following cell:

+Pyrite / acid ferric sulphate / potassium chloride / sodium sulphide / pyrite −

If, on the other hand, two different minerals are involved, the cell may be of a simpler type, like the following:

+Marcasite / potassium chloride / galena −

or

+Marcasite / potassium chloride / sodium sulphide / pyrite −

At each of the above electrodes some local action, either chemical or electric, would doubtless occur immediately; there would remain a residual potential, however, which would be available for producing further effects, possibly at more or less remote points.

If a considerable mass of ore is in contact near the surface with an oxidizing solution—for example, acidified ferric sulphate—and at depth with a less oxidized solution—as ferrous sulphate (there being also any circuitous liquid connection)—electric action should result in the oxidation of the lower solution and reduction of the upper solution until equilibrium is attained. The current would pass downward in the solid conductor and upward in the electrolytic conductor—a vein solution, for example—in which the current would consist in the migration of cations upward and of anions downward. Practically every kind of solution could function to some extent at either one end or the other of the cell suggested. Cathodic effects, such as those described on page 21, would occur chiefly at the upper levels; anodic effects would predominate at the lower levels.

By such "chemical action at a distance"[1] it would seem that the oxidizing and reducing zones would be extended either in one direction or the other somewhat faster and possibly further than by diffusion alone.[2] As a matter of fact the process should probably be conceived not as extending from a given point to a remote point but as creeping along veins by local action, producing an extended zone at an intermediate stage of oxidation or reduction.

In the action suggested above the prime mover, of course, is the ferric sulphate produced by the oxidizing power of the atmosphere, and this oxidizing power of the surface solution is available through electric action at points in front of or below the oxidizing solution. In the same way a reducing solution at depth could exert an influence above it through electric action. As coming events cast their shadows before, a solution of sodium sulphide rising through a metalliferous vein system would by electric action tend to precipitate gold, silver, and copper on the minerals above. Of course, there would be a limit to the extent of either action, a limit set by a lack of proper electric circuits and by polarization, but the essential point is that electric action may cause "chemical action at a distance."

DEPOSITION OF ORES.

Ores are doubtless formed in a great many ways. Some sulphides appear to have been segregated during periods of igneous activity; others occur where obviously there was no igneous activity. In all the varied changes to which the compounds of the valuable metals are subjected fractional solution and precipitation seem to predominate.

---

[1] Ostwald, Wilhelm, Das Chemometer: Zeitschr. physikal. Chemie, vol. 15, p. 399, 1894.

[2] Percolation is entirely another matter and may be fast or slow according to the geologic structure. The electric effects must be of approximately the same order as those of diffusion, yet they may be superposed on diffusion effects and also may set up a selective diffusion of certain ions.

According to Lindgren[1] the chief causes that produce ore precipitation from aqueous solutions are (1) mingling with other waters and (2) reducing agents. It is in the course of these changes that electric activity becomes a factor demanding consideration. One way in which electric action may effect at least ore solutions, and presumably the deposition of ores, by equalizing chemical differences along veins has been mentioned. Another effect of electric activity would be to keep the ores in a polarized state. The citation of known facts to explain the deposition of sulphides must necessarily be conjoined with qualifications due to uncertainty about the solutions. In general, however, the phenomena of deposition would probably be the reverse of those of solution. Other things being equal, an electric potential at which one mineral would be stable might differ from that at which another mineral would be stable. The several sulphides are by no means equally precipitable from solutions containing two or more metallic salts, and though that fact has heretofore been ascribed wholly to specific differences in solubility, there may be reciprocal relations between the electro-affinities of the metals and their precipitation by a sulphide which should be elucidated.

In considering the protection from chemical action afforded by electric polarization, it may be recalled that some metals are rendered "passive" by making them anodes for a short time. Similarly, the polarization of sulphides by positive electrification would undoubtedly preserve them by maintaining around them a film of hydrogen sulphide. Some years ago A. N. Winchell[2] studied the rate of solution of pyrite under certain conditions. His results are almost valueless for our present purposes because, unfortunately, he placed the pyrite upon a screen of metallic aluminum, which must have formed an electrolytic couple with the pyrite and to some extent protected it. Winchell noted the presence of aluminum salt in the solution. Recently Graton and Murdoch[3] have called attention to the fact that pyrite is one of the last of the sulphides to succumb to alteration but note that in decomposing it maintains a bright, clean appearance. The measurements of its potential are consistent with these facts and the brightening effect of a very feeble cathodic polarization of pyrite was noted in the electrolytic experiments.

With a large current almost any metal may be plated out on sulphides; with a smaller current and potential, however, a sulphide may be formed instead of the free metal, just as a forced electrolysis of an acid or of an alkali salt with a mineral sulphide electrode

[1] Lindgren, Waldemar, Econ. Geology, vol. 1, p. 40, 1905.
[2] Winchell, A. N., The oxidation of pyrite: Econ. Geology, vol. 2, p. 291, 1907.
[3] Graton, L. C., and Murdoch, J., The sulphide ores of copper, some results of microscopic study: Am. Inst. Min. Eng. Trans., Feb., 1913.

evolves hydrogen, whereas a feeble current generates a soluble sulphide. Even feeble currents ordinarily precipitate only free gold or silver, but the slow precipitation of copper on even pyrite might produce some cuprous sulphide. So far, however, cuprous sulphide has not been produced electrolytically under conditions that would afford unquestionable results. In the electrodeposition of copper for analytical purposes, in the presence of sulphates, the copper is sometimes tarnished by sulphide, but it is doubtful whether this observation is applicable in a theory of ore deposition. If, however, electric currents might direct metallic ions toward the conducting sulphides, the metathetical reactions which would then occur are clearly indicated by Schürmann's series.[1] The suspicion that electric factors are not wholly negligible, even in metathetical reactions involving metallic ions, is greatly strengthened by the fact that there is a rough parallelism between Schürmann's series and the "electrolytic potential" series of the metals to be considered below. At present, however, there are absolutely no data on the subject.

More definite statements can be made about the metals than about the sulphides, as their behavior has been shown by many experiments in electroanalysis and related chemical processes. From a mixture of metallic salts in solution the metal of lowest solution tension will tend to deposit first in electrolysis, in accordance with the well-known "deposition potentials." The following table of electrolytic potentials gives the value assumed by the metal in a solution normal with respect to the metallic ion:[2]

Electrolytic potentials.

Au +1.356	Sb +0.743	H +0.277	Tl −0.045
Pt +1.140	Bi + .688	Pb + .129	Fe − .063
Pd +1.066	As + .570	Sn + .085	Cd − .143
Ag +1.048	Cu + .608	Ni + .049	Zn − .493
Hg +1.027		Co + .045	Mn − .798

Some of the above values have been changed from time to time as better determinations of the ionic concentrations have been made, the latest value for silver being 1.06 volts, and for gold, about 1.8.[3]

It will be noticed that gold, platinum, palladium, silver, and mercury show higher potentials in normal solutions of their respective ions than most of the minerals that have been studied show in salt solutions. Therefore, in cells constructed as follows:

+ Metal / metal solution / potassium chloride / conducting mineral −

these metals deposit spontaneously until polarization puts a stop to the action. In such a cell the mineral is oxidized simultaneously

[1] For the latest discussion of the application of this series see Emmons, W. H., The enrichment of sulphide ores: U. S. Geol. Survey Bull. 529, 1913.

[2] Wilsmore, N. T., Ueber Elektroden-Potentiale: Zeitschr. physikal. Chemie, vol. 35, p. 318, 1900.

[3] *Abegg*, Handbuch der anorganischen Chemie, vol. 2, pt. 1, pp. 674, 788, 1908.

with the deposition of the gold, silver, or other metal. In speculating on the starting of such action in nature it may be noted that most specimens not only have "points of weakness" but that in nature several sulphides are likely to be in association so that deposition seems likely to start unequally. No specimens of commercial iron and steel are so uniform throughout in composition or texture that some local electric action does not occur when they are immersed in solution.[1] In such specimens there are always some points of greater "solution tension" than others. We may perhaps assume that ores will also vary somewhat in structure or composition. When deposition has started, the metal deposited is very likely to serve as cathode for the deposition of more, and the principal factor limiting electric action is then the polarizability of the oxidizing sulphide. (See p. 18.) In this way the natural occurrence of filaments and nuggets may be very readily explained as due to electrodeposition in which the oxidation of a mineral more or less removed from the metal, if only still connected by the thinnest metallic thread, is an essential part of the process. That silver deposited by electrolysis is prone to form beautiful crystals is well known, although I am not aware that gold crystals have been so produced in the laboratory. I have observed nuggets of gold, however, which possessed a crystalline "treelike" structure exactly like that so well manifested by silver.

In order to see how solutions of the above-mentioned metals would affect pyrite, the following experiments were performed: Small weighed pieces of pyrite were placed in solutions of gold, platinum, and silver. It was found that 5.2 milligrams of gold were precipitated on a gram of pyrite in two days from a chlorauric acid solution. Platinum was not visibly deposited in the same time from a chlorplatinic acid solution, but after several days 0.4 milligram was deposited. A piece of pyrite gained 0.3 milligram after standing in a silver nitrate solution for 10 days.[2]

A number of qualitative experiments of a similar character are described by Skey.[3] One or two quotations will show the nature of his experiments:

> I therefore agitated a little finely powdered galena with a weak solution of terchloride of gold, omitting the addition of organic matter and taking every precaution against its presence accidentally, when I found, after a little while, the gold solution had become quite colorless, and on testing it not a trace of this metal could be found;

[1] Cushman and Gardner, Corrosion and preservation of iron and steel, p. 51, 1910.

[2] Very interesting and much more extended experiments of a like nature have since been made by Chase Palmer and E. S. Bastin, who investigated the behavior of a large number of metallic minerals as precipitants of silver and gold and classified them with regard to their activities. See Econ. Geology, vol. 8, pp. 140-170, 1913. See also the results of the work of A. C. Spencer, in Econ. Geology, vol. 8, p. 629, 1913.

[3] Skey, W., On the reduction of certain metals from their solution by metallic sulphides, and the relation of this to the occurrence of such metals in the native state: New Zealand Inst. Trans. and Proc., vol. 3, p. 225, 1870.

it had evidently been absorbed, as it were, by the galena, and, in fact, a careful inspection of the mineral showed it to be feebly gilded. * * *

Chloride of gold was also found to be reduced by contact with the following sulphides—sulphides of iron, copper, zinc, tin, molybdenum, lead, mercury, silver, antimony, bismuth, arsenic, platinum, and gold; and among the arsenides, mispickel and arsenide of silver; cubical iron pyrites is rather slow in its action upon this solution of gold, while sulphide of antimony scarcely affects it at all at first, but after some hours contact with it reduction goes on rapidly, perhaps by aid of some voltaic action. All these effects were produced at common temperatures (with the exception of that with sulphide of bismuth), while other experiments with iron and copper pyrites prove that similar effects are produced when all kind of light is excluded, so there is no reason to suppose that light has been concerned in any of these reactions. * * *

A portion of the metal of the sulphide operated upon was uniformly found in the solution afterward, and also sulphuric acid; the mode, therefore, in which these effects were produced was evidently by the oxidation of both the constituents of the nucleus employed at the expense of the chloride of gold. * * * Enough has been discovered to show that silver and one or more of the metals of the platinum series are reduced from their soluble salts by these substances generally. * * *

When common iron pyrites and galena are placed in dilute acids or saline solutions within a short distance of each other and connected by platinum wires with a solution of gold chloride contained in a separate vessel, it will be found, after the expiration of a few hours, that the wire connected with the galena has been well gilded over that end of it submerged in the gold solution * * *.

These results, taken in connection with the abundance of metallic sulphides in many of our mineral veins and rocks, make it appear very probable that much of our native gold, silver, and platinum have been electrodeposited from saline solutions by voltaic action set up by the contact of dissimilar sulphides, or sulphides with more negative substances, such as hematite, magnetite, or ferruginous rocks.

The tendency of metals to precipitate by electrodeposition may be expressed quantitatively by the well-known formulas for the potentials of concentration cells. Since this tendency decreases with diminishing concentration, it should be possible to calculate the degree of dilution at which solutions of gold, copper, or silver would cease to deposit the metals at a given potential. The calculation is as follows: Let the given potential be +0.50 volt, a value about equal to that found for galena in dilute salt solutions: How dilute must a solution of a metal be to give this potential against the metal?

The following equations express the relation between the potentials of gold, silver, and copper in solutions of their salts and the concentrations of the salts:

$$E_{Cu}{}^{++} = 0.61 + 0.029 \log C_{Cu}{}^{++}$$
$$E_{Ag}{}^{+} = 1.06 + 0.059 \log C_{Ag}{}^{+}$$
$$E_{Au}{}^{+} = 1.8 + 0.059 \log C_{Au}{}^{+}$$

in which C, the concentration of the respective ions Cu^{++}, Ag^{+}, and Au^{+}, is expressed in gram equivalents per liter. Substituting 0.50 for E in each equation and solving for C we have:

$$C_{Cu}{}^{++} = 4.2 \times 10^{-4}$$
$$C_{Ag}{}^{+} = 1.1 \times 10^{-10}$$
$$C_{Au}{}^{+} = 0.9 \times 10^{-22}$$

Solutions whose normality is lower than the numbers just given would have no tendency to overcome a voltage of +0.50. It is seen that such a solution would be exceedingly dilute for gold (not quite so dilute for the metal as the number given for the aurous ion because gold solutions are not completely ionized into aurous ion, but still very dilute), very dilute for silver, and rather dilute for copper. Similar calculation could be made for other potentials than 0.50 volt.

Deposition of the valuable metals could be brought about not only at the expense of an oxidizable mineral in the manner just considered but also by a combination of a rather inert mineral like pyrite with any reducing solution. The cell would be of this form:

+Pyrite / metal solution / reducing solution / pyrite−

As a very simple demonstration of this mode of action in the deposition of silver from silver sulphate by sodium sulphide the following experiment was performed: A few drops of silver sulphate solution were placed on the smooth face of a large crystal of pyrite. Some distance away, on the same crystal, a few drops of sodium sulphide were placed. The two solutions were then connected by a small U-shaped capillary tube filled with water. In the course of an hour crystals of silver could be distinguished on the pyrite in the silver sulphate solution. This experiment shows how associations of the valuable metals with conducting minerals may be produced in nature by the electromotive power of reducing solutions at another point. This mode of action was mentioned on page 64 under the heading "General conditions."

The present study is not to emphasize the fact that sulphides, either soluble or insoluble, are capable of reducing solutions of gold, silver, and certain other metals, for that has long been known, but to show that electric action may produce forms and associations of those metals which can not be explained otherwise.

SOLUTION OF ORES.

The solution of ores may be the result of many different chemical agencies, but the facts presented in the preceding pages indicate that electric action may be one of the factors where conducting minerals are present. The evidence afforded by experiment shows that a current passing from mineral to solution will produce oxidation—of the solution first if it is oxidizable, otherwise of the mineral. The order in which the various solutions would be oxidized is shown by the table on page 56. Alkali sulphides would go first, then alkali hydrosulphides, if present, and finally the ores, if no further reducing agents were present in the solution. Of several ores, the one of lowest potential would tend to be oxidized first.

Although the order in which the substances other than ores would be oxidized in ore deposits is here stated, it is believed, for the first time, the fact that this principle was applied to ores long ago by Skey seems to have been generally overlooked. Skey says:[1]

> In a natural way, therefore, the contact of dissimilar sulphides generally should set up galvanic action and chemical decomposition, and by setting up this action we might have an easily decomposable sulphide preserved by the association with it of one still more ready to decompose.

The increased oxidation of one sulphide in contact with another was noted in chemical studies by Gottschalk and Buehler before they developed an explanation in terms of electric action.

The results of experiments suggest that magnetite, marcasite, pyrite, and chalcopyrite should be more resistant to oxidation, and that chalcocite, pyrrhotite, and galena should be oxidized more rapidly than the former when in contact with them. A very important factor in any electric action, however, is the polarizability of the electrodes. The study of their polarizability showed that certain minerals were oxidized in the following order, the series beginning with the one which would be oxidized most rapidly: Iron, copper, silver, chalcocite, galena, pyrrhotite, covellite, marcasite, chalcopyrite, pyrite, and magnetite. It should be emphasized that this series shows speed effects, which may constitute an important factor in the alteration of the ores. The series by itself is probably not sufficient to indicate an order of occurrence in nature, nor does the order correspond exactly with the electromotive series; both series are significant, but their application must depend on the nature of the conception of the phenomena taking place in ore deposits—that is, whether they are viewed as equilibria or as effects of varying rates of oxidation. With the principle that the mineral of lowest potential will tend to be oxidized first must therefore be linked a second principle—that every electrolytic process is accompanied by corresponding polarization. For example, pyrrhotite shows a lower potential than pyrite in a salt solution, but if a current passes from the pyrrhotite to the pyrite through the solution it forms alkali sulphide around the pyrite and the effective electromotive force falls to millivolts or less. There are countereffects in electrolytic action at every stage, and the speed of such action would under many conditions be limited by processes of diffusion.

Electrochemists are familiar with a class of feeble currents known as "residual currents." For example, the application of a low electromotive force to the electrolysis of water with platinum electrodes soon "polarizes" the electrodes with hydrogen and oxygen; further current flows only as fast as the gases dissolve in the solution and dif-

[1] Op. cit., p. 224. See Hunt, Geol. Survey Great Britain, Mem. vol. I.

fuse out of it into the air. The disappearance of an unstable mineral might be the supposed ultimate result of electric action between two or more ores, but practically this would occur very slowly on account of the accumulation of certain products of the reaction; in short, an equilibrium would be attained which would by no means be incompatible with the existence of two or more minerals. The disappearance of one would require a very long continued supply of fresh solution and the removal of the solution products. Specially rapid action, however, would be developed by the alternate drying and wetting of particles of different ores in contact. Traces of ferric salts that would form on iron minerals when dry would exert high potentials when moistened. This seems to be the condition under which Gottschalk and Buehler obtained the most notable effect of acceleration in the oxidation of one sulphide by another in the laboratory.

It is hardly necessary to point out that the order of solution of metals under electric action would be the opposite of the order of their precipitation—that is, when in contact the base metals would oxidize and dissolve first, then copper before silver, and finally silver before gold. Speaking broadly, the base metals would also protect most sulphides from oxidation if in contact with them in the presence of water, and the sulphides would protect silver and gold. Native silver and gold, as we now find them, may therefore have been held in their present position for a long time partly by the presence of sulphides which have now just about disappeared.

To summarize the electric activity of ores very briefly: Contact with solutions as well as certain other conditions impart electric potentials to conducting minerals. When local or electrolytic action is possible the chemical and electric differences will proceed toward equalization by processes of diffusion, decomposition, solution, oxidation, and reduction until the system reaches electrochemical equilibrium. Measurements of potentials are helpful in indicating the direction of possible changes and in giving a quantitative statement of the intensity by which the differences tend to become equalized.

All the experimental results on electric potentials that are here reported or that may hereafter be presented must necessarily be in harmony with natural occurrences, for electric potentials are a quantitative expression of the intensity factor of the "available" energy in chemical systems, and every change that takes place spontaneously in a system in nature can do so only with a diminution of the "available" energy. Where electric conductors are present, electric activity therefore goes on simultaneously with chemical activity and is a means by which chemical differences can frequently be adjusted more rapidly than otherwise.

SUMMARY.

A large number of metalliferous minerals are capable of conducting electricity and could therefore function as electrodes and as conductors for electric currents in ore deposits. In this paper only bare mention has been made of the possible existence of induced earth currents and thermoelectric currents, inasmuch as the field results of Barus on this point were almost wholly negative. It has been shown, however, that the energy which ordinarily manifests itself in chemical reactions may be, and in fact will be, manifested to some extent in electric action whenever the proper circuits are present. Conditions for electric action in ore deposits are by no means unusual. One of the simplest possible combinations by which electric action could occur would consist in the presence of two different active solutions in contact with a single body of ore, the two active solutions being united by any "indifferent" electrolyte. The combination suggested would have many ramifying variations, depending on the amounts of solution available, the position of the ores, and other like factors. The effects of electric action are naturally somewhat different from those which would result from direct admixture of solutions and entirely different mineral associations might be produced through such action.

The chemical difference producing the largest electric effects appears to be that existing between oxidizing and reducing solutions. All solutions may be arranged in an electromotive series grading, speaking broadly, from the strongest oxidizing solutions, which will charge an unattackable electrode most positively, to the strongest reducing solutions, which will charge it most negatively. It has been found that pyrite, and, to a less extent, several other minerals, are so inert to many solutions as to function electrically like "unattackable" electrodes for long periods, thus making oxidizing or reducing solutions available for producing electric currents in ore deposits. The solution products of minerals themselves may take part in producing currents in the absence of more active substances; accordingly, different minerals show different electromotive forces in "water."

The currents generated in any of these ways may cause effects at more or less remote points. Electric action on a large scale would tend to maintain a common level of oxidization along veins and large bodies of ore; where it is effective, the zones of oxidation and reduction would depend on the structure of the ore rather than on depth. Electric action on a small scale would polarize ores feebly, favoring the disappearance of unstable ores and protecting stable ores up to the point of equilibrium. The cathodic and anodic phenomena attending the passage of a current from a solution to a mineral, or vice versa,

have been studied in some detail. It has been found that mineral electrodes possess various degrees of polarizability. The polarization of minerals would doubtless to some extent influence metathetical reactions in ore deposits. Feeble currents might also give a directional trend to metallic ions that would carry them toward the stable minerals. Under many conditions the valuable metals would be deposited from solutions by electrolytic action and they would thereafter be protected from redissolving by contact with any of the more oxidizable ores.

INDEX.

A. Page.

Abt, A., thermoelectric series of.............. 20
Air, apparatus for boiling out, figure showing. 35
exclusion of, effect on potential........ 36, 39, 42
Alkalinity, development of, by electric action. 22
effect of, on oxidizing power.............. 60
Allen, E. T., cited........................... 9
Antimony, potential of....................... 56

B.

Bancroft, W. D., experiments of........... 11, 47, 61
Barus, Carl, work of.......................... 5, 6, 8, 72
Bastin, E. S., work of......................... 6
Batteries, natural, occurrence of.............. 20
Becker, G. F., cited........................... 20
work of.................................... 5
Becquerel, A. C., cited........................ 8
Behrend, R., cited............................ 45
Bernfeld, I., cited..................... 9, 22, 25, 43, 44
Bismuth, sulphide, potential of............... 44
Braun, F., cited............................. 8, 25
Brokaw, A. D., work of........................ 5
Buehler, V. A., and Gottschalk, H. A., work of.......................... 5, 6, 9, 70, 71

C.

Cadmium, potential of 56
Capillary spaces, deposition in............... 8
in galena, polarization in................. 22
Cathode combination, definition of........... 21
Chalcocite, polarization of.................. 16, 18
Chalcocite, potential of..................... 15, 29
Chalcopyrite, polarization of.............. 17, 18
potential of............................... 35
Chemical action, possible range of............ 64
Chemical differences, electromotive force generated by............... 19-20, 62, 71, 72
Chemical reduction, relation of, to electric reduction.......................... 19-20
Cobalt, potential of, in a soluble sulphide.... 45
Compatibility of minerals and solutions... 55, 61, 62
Comstock lode, electric activity in........... 8
Conductivity of minerals, irregularities in data on......................... 25
scale of................................. 24-25
Conductivity of solutions.................... 21
Copper, electro deposition of, on pyrite...... 21, 66
polarization of........................... 18
potential of, in a soluble sulphide....... 45
in water............................. 56
in solutions of cupric salts........... 68-69
Corrosion by electric action, occurrence of.... 9, 21
Covellite, polarization of.................. 16, 17, 18
Crystals, formation of, possible electric influences on..................... 63
Cupric chloride, electric reduction of......... 23
Cuprous chloride, electrolytic production of.. 22
potential of............................. 56

Page.

Currents, earth, residual, origin of........... 14-15
production of, by a difference in the electrode........................ 15
by a difference in the solution....... 14

D.

Deposition, electric, conditions of............ 65-66
of metals on minerals, occurrence of..... 21
Depth, relation of, to electric potential..... 7, 12, 64
Diffusion, electromotive force developed by.. 20, 62
Dufet, H., cited............................ 25

E.

Earth, electric currents in.......... 19-21, 26, 62-73
electric currents in, intensity of.......... 20, 72
free oxygen and hydrogen in solutions in. 60
See also Ores; Depth.
Electric reduction, relation of, to chemical reduction...................... 19-20, 71
Electrodes, polarization of................... 12-18
Electrodes, mineral and platinum, comparison of............................... 10
supply of solution to, without air, figure showing.......................... 27
Electrolysis, alteration by................... 21-23
of minerals, as anodes.................... 23
as cathodes.......................... 21
Electrolyte, variation in, effect of............ 9-11
See also Solutions.
Electrolytic potentials, table of.............. 66
Electromotive force, direction of, between minerals......................... 15
magnitude and continuance of, from minerals............................ 12-19
experiments in, figure illustrating... 13
measurement of, method of.............. 26
relation of, to chemical differences..... 11, 71, 72
Electromotive scale of minerals, investigation of.............................. 8, 56
Electrostatic separation, theory of 24
Emmons, W. H., work of.................... 6
Error, source of, in measurements involving sodium hydrosulphide........... 49
Eureka, Nev., electromotive forces at........ 8

F.

Faraday, M., cited.......................... 25
Ferric-ferrous sulphate solution, effect of, on potentials....................... 27
reduction of.......................... 19-20, 27
effects of............................ 21-23
Ferric sulphate solution, effect of, on potentials........... 13, 13-14, 17-18, 28, 32, 36
effect of, on potentials, apparatus for ascertaining.......................... 28
apparatus for ascertaining, figure showing......................... 27
potential of............................. 56

Page.

Ferrous sulphate solution, effect of, on potential ... 14, 32, 40
potential of ... 56
Fisher, F., cited ... 57
Fox, R. W., cited ... 7, 12, 24

G.

Galena, behavior of, with acids ... 42
electrodeposition on ... 68
polarization of ... 16, 18
potential of ... 10, 14–18, 28, 29, 35, 42–44, 56
effect of solutions on ... 42
Gold, electrodeposition of ... 21, 22, 66–68
polarization of ... 17, 18
potential of ... 56, 68–69
protection of, by sulphides ... 71
Gottschalk, H. A., and Buehler, V. A., work of ... 6, 9, 70, 71
Graton, L. C., work of ... 6
Graton, L. C., and Murdoch, J., cited ... 65

H.

Heberlein, E., and Küster, F. W., cited ... 48
Henwood, W. J., cited ... 7
Hittorf, W., cited ... 21, 47
Hydrogen, action of, on galena ... 36
evolution of, on a mineral electrode ... 21
potential of ... 56, 57–60
chart showing ... 58
Hydrogen sulphide, neutralization of excess, in NaSH ... 49
relation of, to potential ... 36, 40, 42, 46, 47, 49

I.

Ions, migration of, in electric activity ... 21
Iron, electric deposition of, on pyrite ... 21
polarization of ... 18
potential of ... 56

K.

Knox, Joseph, cited ... 43–44, 47–48
Küster, F. W., cited ... 47, 51
Küster, F. W., and Heberlein, E., cited ... 48

L.

Lead, potential of ... 45, 56
Lead dioxide, potential of ... 56
Lead sulphide, artificial, potential of ... 43
See also Galena.
Lehner, Victor, work of ... 5
Leith, C. K., and Van Hise, C. R., work of ... 5
Lewis, G. N., cited ... 57, 60
Lindgren, W., cited ... 65
Luther, R., cited ... 12

M.

Magnetite, polarization of ... 17, 18, 41
potential of ... 10, 15, 41–42
reduction of ... 22
Manganese, potential of ... 56
Manganese dioxide. *See* Pyrolusite.
Manganese nitrate, effect of, on potential of pyrolusite ... 30–31
sulphate, effect of, on potential of pyrolusite ... 31
Manganite, potential of ... 31, 56

Page.

Marcasite, influence of, on oxidation and solution ... 9
polarization of ... 16, 17, 18
potential of ... 15, 27, 28, 29, 35, 39–41, 56
reduction of electrolyte by ... 22
Membranes, semipermeability of ... 8
Mercuric sulphide, potential of ... 45
Mercury, electric deposition of ... 22, 66–67
potential of ... 56
Minerals, combinations of solutions and, effects of ... 12–19, 60–62, 72
currents flowing from solutions to. *See* Solutions.
disappearance of, conditions governing ... 70, 71
electric action of, in solutions of themselves ... 29–30, 38, 72
electric and chemical oxidation of, relations of ... 19–20
electromotive scale of ... 24–25, 56
investigation of ... 8, 9
observation of, in solution, cell for, figure showing ... 29
oxidizing powers of ... 16, 17
polarization of ... 12–18
potentials of ... 55–56
effect of earlier solution on ... 30
effect of different solutions on ... 10–14, 19, 26
apparatus for testing, figure showing ... 13
in water ... 29
thermoelectric scale of ... 29
See also Ores.
Minerals, different, potentials of, in the same solution ... 15, 19
Murdoch, J., and Graton, L. C., cited ... 65

N.

Nickel, potential of ... 45, 56
Nuggets, production of ... 67

O.

Ores, combinations of, resemblance of, to galvanic combinations ... 7
deposition of ... 64–69
application of electric activity to ... 62–73
beginning of ... 67
electric currents in, effect of ... 6, 65, 71, 72–73
generation of ... 62–64
electric oxidation of ... 23, 69–70
solution of ... 69–71
order of ... 71
See also Minerals.
Ostwald, W., cited ... 8, 64
Oxidation, order of, relation of potentials and ... 69
Oxygen, potential of ... 56, 57–60
potential of, chart showing ... 58

P.

Palladium, electric deposition of ... 66–67
Palmer, Chase, work of ... 5
Peters, R., cited ... 11
Platinized electrodes, effect of, in sulphide solutions ... 46

	Page.
Platinum, electrodeposition of	21, 22, 66–67
polarization of	13–15, 16, 17
potential of	10, 13–14, 16–17, 28, 29, 35, 56
Polarization, possible cause of, in ores	63
effect of, on ore deposition	65, 70
of minerals, as anodes	16
as cathodes	18
of pyrite in detail	36
Polysulphides, soluble, decomposition of, by water	52
electromotive behavior of	51–54
effect of dilution on	51
probable complexity of	53–54
Potassium arsenite, potential of	56
Potassium chlorate solution, effect of, on potential	14
Potassium chloride solution, effect of, on potential	10, 14–18, 31, 34–36, 39, 41, 42, 50
Potential, apparatus for obtaining, of minerals in water	38
constancy of	10–11, 26, 29, 34
effect of different solutions on	10, 55
oxidation and reduction, variations of	11
relation of oxidation and	69
variation in, relation of, to oxidizing power of solutions	11–12
Potential, single, measurement of	26–45
measurement of, correlation of	54–62
errors in, cause of	55
See also particular minerals.	
Preuner, G., cited	59–60
Prospecting, relation of electric activity to	6, 8
Pyrite, anode and cathode changes in	23
electric deposition on	22, 23, 67
influence of, on oxidation and solution	9, 72
oxidation of	19
polarization of	16, 17, 18, 36–37
chart showing	37
potential of	10, 12–18, 27, 28, 29, 32–39, 54, 56
lag in	37–38
relation of, to electrolyte	32–33, 38–39, 72
reduction of ferric sulphate by	19, 21–23
saturated solution of, apparatus for, figure showing	38
solution of	65
Pyrolusite, polarization of	16, 17, 32
potential of	30–32, 56
reduction of	22
Pyrrhotite, anode and cathode changes in	23
polarization of	16, 17, 18
potential of	10, 15, 27, 29, 41, 56
reduction of electrolyte by	22
R.	
Reductions, effects of electric	21–23
Reich, F., cited	7
Residual currents, origin of	14–15, 70–71
S.	
Schürmann's series, application of, possible qualification in	66
Silver, electrodeposition of	21, 22, 66–67, 69
potential of	45, 56, 68–69
protection of, by sulphides	71
by copper	71
Silver sulphide, potential of	44, 45
Skey, W., cited	7–8
quoted	67–68, 70
Smith, G. O., preface by	5–6
Sodium hydrosulphide solution, potential of	56
preparation of	48–49
source of error in measurements involving	49
Sodium hydrosulphide, relation of, to potentials	28–29, 33, 43, 44, 45
Sodium hydroxide solution, potential of	56
relation of, to potential	11, 14–15, 30–31, 32–33, 39, 41, 42, 50
Sodium polysulphide solution, reduction of	23
relation of, to potential	32
Sodium sulphide solution, dilution of, effect on potential	51–54
potential of	56
electric formation of, from minerals	22, 23
relation of, to potential	10, 14, 33, 43
Sodium sulphite, potential of	56
Solutions, character of, importance of, in determining electromotive behavior	26, 72
combinations of minerals and, effects of	12–19, 60–62
currents flowing from minerals to	23
currents flowing to minerals from, effects of	21–23
effects of, on mineral potentials	6, 10, 12–15, 20, 26, 29–30
apparatus for testing, figure showing	13
observation of minerals in, cell for, figure showing	29
oxidizing power of, relation of, to potentials	11–12
supply of, to electrodes, without air, figure showing	27
variation in, effect of	9–11
Spencer, A. C., work of	67
Stannous chloride, potential of	56
Stromberg, A. von, cited	7
Sulphide electrodes, behavior of	49–50
Sulphide potentials, definition of	39, 46
Sulphides, iron, potentials of	27
Sulphides, solid, thermoelectric action between	20
Sulphides, soluble, bearing of, on behavior shown by minerals	54
concentration of, relation of, to potential	47–48
electromotive behavior of	45–54
potentials of, relation of, to concentration	47–48
reducing power of	45–46
Sulphides as anodes, effect of current on	23
Sulphides as cathodes, effect of current on	21–23
Sulphur, possible ionization of	50
potential produced by presence of	49–50
Sulphuric acid, effect of, on potentials	10, 14, 30–31, 32
potential of	56
T.	
Temperature, effect of, on conductivity	25
Thermoelectromotive forces, development of	20
Tower, O. F., on potential of pyrolusite	30–31

V. Page.

Van Hise, C. R., and Leith, C. K., work of .. 5

W.

Water, potential of minerals in........ 29-30, 38, 72
modification of, by dissolved salts....... 56
by metals.......................... 57
by minerals.......................... 56, 60
free oxygen and hydrogen in............ 59

Wentworth, H. A., on conductivity of minerals........................... 24
Wilsmore, N. T., cited....................... 60, 66
Winchell, A. N., cited....................... 65

Z.

Zengelis, K., cited........................... 45
Zinc, potential of............................ 56

O

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 549

THE SHINUMO QUADRANGLE

GRAND CANYON DISTRICT
ARIZONA

BY

L. F. NOBLE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

CONTENTS.

Page.

Preface, by F. L. Ransome........ 7

Introduction........ 11

Location and geography........ 11

Field work........ 13

Literature........ 13

Acknowledgments........ 15

Physiography of the Grand Canyon district........ 15

Topography of the Shinumo quadrangle........ 21

Climate........ 25

Vegetation........ 27

Indian ruins........ 28

Geology........ 29

Age and character of the rocks........ 29

Series of rocks discriminated........ 31

Proterozoic rocks........ 32

Archean system........ 32

Vishnu schist........ 32

Name........ 32

Distribution in the Grand Canyon........ 32

Occurrence and distribution in the Shinumo quadrangle........ 32

Types of the schist........ 33

Lithology of the types........ 33

Origin of the schist........ 34

Age and correlation........ 35

Intrusive quartz diorite and dikes of pegmatite associated with the Vishnu schist........ 35

Quartz diorite........ 35

Pegmatite........ 36

Algonkian system........ 37

Grand Canyon series........ 37

Name........ 37

Distribution in the Grand Canyon........ 37

Structure and distribution in Shinumo quadrangle........ 39

Unkar group........ 40

Character and subdivisions........ 40

Hotauta conglomerate........ 42

Bass limestone........ 43

Hakatai shale........ 48

Shinumo quartzite........ 51

Dox sandstone........ 53

Comparison with type section in Unkar Valley........ 53

Age and correlation of the Grand Canyon series........ 54

Geology—Continued. Page.
Proterozoic rocks—Continued.
Algonkian system—Continued.
Grand Canyon series—Continued.
Intrusive diabase associated with the Unkar group.......... 55
Occurrence.. 55
Petrography.. 56
Variations in character.................................. 56
Contact metamorphism.................................. 57
Asbestos.. 58
Age of diabase.. 60
Paleozoic rocks.. 60
Results of previous work in the region........................ 60
General succession of the Paleozoic rocks........................ 61
Cambrian system.. 61
Tonto group.. 61
Tapeats sandstone.. 61
Bright Angel shale.. 62
Muav limestone.. 64
Correlation of Tonto group.. 65
Unconformity.. 65
Carboniferous system.. 66
Redwall limestone.. 66
Aubrey group.. 68
Supai formation.. 68
Coconino sandstone.. 69
Kaibab limestone.. 70
Variations in thickness of the Paleozoic strata........................ 71
Effect of the variation in thickness of the Paleozoic strata upon topography of the canyon wall.. 73
Structural geology.. 75
West Kaibab fault.. 75
Faults of the Unkar wedge.. 77
Displacements of the Paleozoic strata.. 78
Geologic history.. 80
The sedimentary and erosional record.. 80
The plateau problem.. 88
Scenic interest of the Shinumo quadrangle.. 91
Copper deposits of the Shinumo quadrangle.. 93
Index.. 97

ILLUSTRATIONS.

		Page.
PLATE I.	Geologic map of Shinumo quadrangle, Ariz., with structure sections	In pocket.
II.	*A*, Traveling on trail in Grand Canyon with pack train; *B*, At Bedrock tank, Bass Canyon	12
III.	*A* and *B*, Views up Colorado River near Cable Crossing	16
IV.	*A*, Panoramic view of Powell Plateau across Muav Saddle from the Kaibab Plateau; *B*, Panoramic view of Unkar wedge from Tonto platform	18
V.	Tonto platform: View eastward up Kaibab division of Grand Canyon from level of the Esplanade directly under Havasupai Point	20
VI.	The Esplanade: View northwestward from Havasupai Point	21
VII.	A, View northward from Bass Camp; *B*, View eastward from the summit of Mount Huethawali	22
VIII.	*A*, East wall of canyon of Shinumo Creek near Shinumo garden; *B*, View eastward up Colorado River from a point near the mouth of Bass Canyon	28
IX.	Generalized columnar section of the rocks of Shinumo quadrangle	30
X.	*A*, Bass limestone in Hotauta Canyon; *B*, Strata of Unkar group near mouth of Bright Angel Creek	38
XI.	View northward across the Grand Canyon from the end of Grand Scenic Divide	39
XII.	Shinumo quartzite: *A*, North of Cable Crossing; *B*, In canyon of Shinumo Creek, showing garden	52
XIII.	*A*, View near Cable Crossing, looking down Colorado River; *B*, Dox sandstone in canyon of Shinumo Creek	54
XIV.	Lower contact of diabase sill: *A*, On Shinumo Creek; *B*, At Bedrock tank, Bass Canyon	55
XV.	*A*, Muav limestone in Muav Canyon; *B*, Faults in Unkar wedge in canyon of Shinumo Creek	64
XVI.	*A*, Pinnacles of erosion (hoodoos) in Kaibab limestone along rim of Kaibab Plateau; *B*, Wheeler fold in Bass Canyon	78
XVII.	*A*, Wheeler fold from bed of Bass Canyon; *B*, Faulting in strata of the Unkar wedge in Burro Canyon	79
XVIII.	Geologic history of the Shinumo quadrangle as revealed in the canyon wall	86
FIGURE 1.	Index map showing location of Shinumo quadrangle	12

PREFACE.

By F. L. Ransome.

Ever since Powell's daring boat trip down the Colorado in 1869 geologists have known that the walls of the Grand Canyon display one of the most remarkable and instructive geologic sections in the world. At first glance the impressive feature of that section is the great thickness of nearly horizontal strata through which the river has sunk its bed—strata ranging in age from Carboniferous (Pennsylvanian) at the top, on the brink of the chasm, to Cambrian at the base. Powell found, however, that unconformably below the Cambrian in certain portions of the canyon there are extensive remnants of an older and much thicker series of sediments in beds which had been upturned into mountains and truncated by prolonged erosion before the sands of the Cambrian sea covered them. These beds he called the Grand Canyon group and described as resting with profound unconformity on the vastly more ancient crystalline rocks into which the river has also cut deeply in the so-called Granite Gorge.

In 1882 appeared Dutton's well-known "Tertiary history of the Grand Canyon district," which dealt mainly with the erosional development of the canyon and barely touched upon the earlier chapters of the geologic history recorded in its walls.

Between 1883 and 1895 Dr. Charles D. Walcott, in a number of papers, described in greater detail the Grand Canyon group of Powell, dividing it into an upper or Chuar terrane, 5,120 feet thick, and a lower or Unkar terrane, 6,830 feet thick. He assigned both to the Algonkian system, showed that the conformably overlying sandstone is Cambrian, not Carboniferous, as had been supposed by Powell and by Dutton, and applied the name Vishnu terrane to the fundamental crystalline rocks. These he described as micaceous schists and quartzites cut by granite.

During the next 10 or 12 years not much advance was made in our knowledge of the character and stratigraphy of the older rocks in the Grand Canyon, although the period was by no means barren of geologic literature on other problems connected with the growth of that vast abyss. Yet there were awaiting solution a number of problems fully as interesting to students of stratigraphy and pre-

Cambrian geology as are the processes and results of earth sculpture to investigators who are chiefly concerned with the origin of those forms whose collective aspect constitutes what we term scenery. For example: Much remained to be learned about the lithologic character and divisions of the great masses of strata which Walcott had named the Unkar and Chuar terranes. Doubt existed and still exists as to the true character of the fundamental crystalline complex, some observers failing to find in it material recognizable as metamorphosed sediments and seeing at the localities visited by them only such intrusive and highly metamorphosed rocks as are suggestive of igneous origin and Archean age. Within the Paleozoic series the part of the stratigraphic column most obviously in need of study is that between the Cambrian and the Carboniferous, where the Devonian appears to be represented at some localities and absent at others.

Detailed geologic work demands an accurate topographic base map, and no good map of the Grand Canyon existed until the publication, between 1906 and 1908, of the Vishnu, Bright Angel, and Shinumo topographic sheets, on the scale of 1:48,000, very nearly 1⅓ inches to the mile. The topography of these maps, by François E. Matthes and Richard T. Evans, fully meets the requirements of the geologists, and one sheet, the Shinumo, was immediately utilized by the author of the present bulletin in a study devoted particularly to the lithology and stratigraphy of the Unkar group. Begun as a university thesis, the work was completed under arrangement with the Geological Survey.

In his careful measurement, description, and subdivision of the Unkar group Dr. Noble has not only thrown light on the pre-Cambrian history of the Colorado Plateau region, but has supplied geologists who are working in the southwestern part of the country with a standard of comparison for Algonkian strata exposed elsewhere in that region. In addition to pursuing what may be considered the main purpose of the investigation, Dr. Noble has added much to our knowledge of the general geology and erosional history of the Shinumo quadrangle—that is, of the western part of the Kaibab division of the Grand Canyon—and the map which accompanies this bulletin represents the first geologic mapping done in the canyon that attains the standard of accuracy and detail set for the Geologic Atlas of the United States. By describing examples additional to those previously known he has shown the prevalence and structural importance of pre-Cambrian faults and the recurrence of movement in post-Paleozoic time along these ancient fractures. He has also called attention to the influence of minor joints and of fractures not associated with noticeable displacement in guiding the forces of erosion and in determining topographic form.

Although the bulletin contains considerable lithologic and stratigraphic material that will scarcely interest those who are not geologists, Dr. Noble has very properly remembered that the people as a whole have unusual claims to consideration in any publication dealing with the Grand Canyon, and has skillfully supplied as a setting to his more strictly scientific work much vivid description and lucid explanation which will help all those who take more than a transient and superficial interest in what they see to understand one of the most impressive and significant of the inanimate works of nature.

THE SHINUMO QUADRANGLE, GRAND CANYON DISTRICT, ARIZONA.

By L. F. Noble.

INTRODUCTION.

LOCATION AND GEOGRAPHY.

The Shinumo quadrangle, in Coconino County, northern Arizona, is the westernmost of three quadrangles covered by the United States Geological Survey's maps of a part of the Grand Canyon of the Colorado—the Vishnu, Bright Angel, and Shinumo sheets—which show the Kaibab division of the Grand Canyon. The quadrangle is bounded on the north and south by parallels 36° 20′ and 36° 5′. Its eastern and western boundaries are irregular and it lies for the most part between meridians 112° 15′ and 112° 30′, but extends northward somewhat beyond these limits. Its total area is about 270 square miles.

The only permanent habitation in the quadrangle is Bass Camp, which is at the rim of the Grand Canyon on the Coconino Plateau, about a mile west of Havasupai Point. The camp was established by Mr. W. W. Bass some 25 years ago to accommodate tourists. From Bass Camp a trail that has been constructed across the Grand Canyon descends its southern wall through Bass Canyon to Colorado River and ascends its northern wall through Shinumo and Muav canyons. The river is crossed by means of a car that travels on wire cables suspended 50 feet above the surface of the stream, so that men and animals may be transported at all seasons of the year regardless of high water (Pl. XIII, *A*, p. 54). The length of the trail from the southern rim of the canyon to the river is 6½ miles; from the river to the summit of the northern wall it is 10 miles. Mr. Bass has recently discovered in the depths of the canyon deposits of copper and asbestos, to which he has constructed additional trails. The trails afford access with pack animals (Pl. II) to all points of geologic interest in the interior of the canyon and to points on Powell and Kaibab plateaus, as well as to settlements in southern Utah. A permanent camp (Pl. VIII, *A*, p. 28) has been established in the depths of the canyon about a mile up Shinumo Creek from the Colorado, where

an irrigated garden (Pl. XII, *B*, p. 52) is now cultivated on the site of one made by the prehistoric inhabitants of the region. Bass Camp is most easily reached from Grand Canyon station on the Grand Canyon Railway, a branch of the Santa Fe System, by a wagon road 25 miles in length. Another road leads southwestward

FIGURE 1.—Index map showing location of Shinumo quadrangle.

from Bass Camp to the rim of Cataract Canyon, about 20 miles away, whence a trail descends to the Havasupai Indian village in Cataract Canyon. Roads also lead to the towns of Williams and Ash Fork, about 60 miles respectively south and southwest of Bass Camp. The north rim of the Grand Canyon is reached by a wagon road across the Kaibab Plateau from the town of Kanab, in southern Utah.

A. TRAVELING ON TRAIL IN THE GRAND CANYON WITH PACK TRAIN.

B. AT BEDROCK TANK, BASS CANYON.

FIELD WORK.

The greater part of the geologic field work on which this report is based was done between August 23 and December 12, 1908, in preparation for a thesis which was presented to the faculty of Yale University in 1909 in partial fulfillment of the requirements for the degree of doctor of philosophy. A part of the thesis, dealing with the Archean and Algonkian rocks of the Shinumo quadrangle has already been published.[1]

In February, 1910, the writer returned to the Grand Canyon to complete, on an enlarged base and in greater detail, the geologic map made to accompany the thesis. This work, begun February 24 and ended March 16, 1910, was done under the direction of the United States Geological Survey. The area covered by this map (Pl. I, in pocket) is somewhat over 200 square miles, or about three-fourths of the Shinumo quadrangle, and includes all exposures of Algonkian rocks in the quadrangle and all features of exceptional geologic interest.

LITERATURE.

Maj. Dutton, in his monograph entitled "Tertiary history of the Grand Canyon district,"[2] describes most fully and charmingly the geology of the north rim in this section of the Grand Canyon. Chapter VII describes the surface features and scenery of the Kaibab Plateau in the vicinity of Point Sublime. Chapter VIII is devoted to the panorama disclosed from Point Sublime, and Chapter IX describes in detail the walls of the amphitheaters of the north side. The Muav Saddle and Powell Plateau are described on pages 162–167 and the Shinumo Amphitheater on pages 167–174. Dutton's work, however, did not extend into the depths of the canyon.

J. S. Diller, of the United States Geological Survey, in reports on the production of asbestos, describes deposits of asbestos occurring in the Algonkian rocks of this area near Bass Ferry. Diller's first report[3] contains the earliest mention of Algonkian strata in this part of the Grand Canyon.

BIBLIOGRAPHY.

BARRELL, JOSEPH, Relative geological importance of continental littoral and marine sedimentation: Jour. Geology, vol. 14, pp. 316, 356, 430–457, 524–568, 1906.

CROSS, WHITMAN, U. S. Geol. Survey Geol. Atlas, Needle Mountains folio (No. 131), 1905.

---

[1] Noble, L. F., Contributions to the geology of the Grand Canyon, Arizona. The geology of the Shinumo area: Am. Jour Sci., 4th ser., vol. 29, pp. 369–386, May, 1910; pp. 497–528, June, 1910.

[2] Dutton, C. E., Tertiary history of the Grand Canyon district, with atlas: U. S. Geol. Survey Mon. 2, 1882.

[3] Diller, J. S., The production of asbestos in 1907; U. S. Geol. Survey Mineral [illegible] pp. 720–721, 1908; also The production of asbestos in 1908: U. S. Geol. Survey [illegible] 2, p. 705, 1909.

Darton, N. H., Reconnaissance of parts of northern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, 1910.
Davis, W. M., An excursion to the Grand Canyon of the Colorado: Harvard Univ. Mus. Comp. Zool. Bull. 38, geol. ser., vol. 5, No. 4, 1901.
———— An excursion to the Plateau province of Utah and Arizona: Harvard Univ. Mus. Comp. Zool. Bull. 42, geol. ser., vol. 6, No. 1, 1904.
Diller, J. S., The production of asbestos in 1907: U. S. Geol. Survey Mineral Resources, 1907, pt. 2, pp. 720–721, 1908.
———— The production of asbestos in 1908: U. S. Geol. Survey Mineral Resources, 1908, pt. 2, p. 705, 1909.
Dutton, C. E., Tertiary history of the Grand Canyon district, with Atlas: U. S. Geol. Survey Mon. 2, 1882.
Frech, F., Section in Congress Canyon opposite Point Sublime: Internat. Geol. Cong., fifth session, Compte rendu, pp. 476–481, 1894. (The supposition that Congress Canyon is opposite Point Sublime is erroneous. Point Sublime is 25 miles west of a point opposite Congress Canyon.)
Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872: U. S. Geog. Surveys W. 100th Mer., vol. 3, pt. 1, pp. 17–187, 1875.
Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Univ. Mus. Comp. Zool. Bull. 42 geol. ser., vol. 6, No. 5, 1904.
Ives, J. C., Report upon the Colorado River of the West: Senate Ex. Doc., 36th Cong., 1st sess., pt. 1, general rept., pp. 13–131, 1861.
Johnson, D. W., A geological excursion in the Grand Canyon district: Boston Soc. Nat. Hist. Proc., vol. 34, pp. 135–161, 1909.
Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, 1908.
Newberry, J. S., Report upon the Colorado River of the West: Senate Ex. Doc., 36th Cong., 1st sess., pt. 3, geol. rept., pp. 1–154, 1861.
Powell, J. W., Exploration of the Colorado River of the West and its tributaries. Explored in 1869, 1870, 1871, and 1872 under the direction of the Secretary of the Smithsonian Institution, 1875.
———— Geology of the eastern portion of the Uinta Mountains, U. S. Geol. and Geog. Survey Terr., 1876.
Ransome, F. L., Geology of the Globe Copper district, Arizona: U. S. Geol. Survey Prof. Paper 12, 1903.
———— The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, 1904.
———— A comparison of some Paleozoic and pre-Cambrian sections in Arizona: Science, new ser., vol. 27, pp. 68–69, 1908.
———— Pre-Cambrian sediments and faults in the Grand Canyon of the Colorado: Science, new ser., vol. 27, No. 695, pp. 667–669, 1908.
Robinson, H. H., The Tertiary peneplain of the Plateau district and adjacent country in Arizona and New Mexico: Am. Jour. Sci., 4th ser., vol. 24, pp. 109–129, Aug., 1907.
———— A new erosion cycle in the Grand Canyon district, Arizona. Jour. Geology, vol. 18, No. 8 (Nov.-Dec., 1910), pp. 742–763, 1910.
———— The single cycle development of the Grand Canyon of the Colorado: Science, new ser., vol. 34, No. 864, 1911.
Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Arizona: Am. Jour. Sci., 3d ser., vol. 20, pp. 221–225, 1880.
———— Pre-Carboniferous strata in the Grand Canyon of the Colorado, Arizona: Am. Jour. Sci., 3d ser., vol. 26, pp. 437–442, 484, 1883.

RANSOME, E. L., Study of a line of displacement in the Grand Canyon of the Colorado in northern Arizona: Geol. Soc. America Bull., vol. 1, pp. 49, 1890.

———— Pre-Cambrian igneous rocks of the Unkar terrane, Grand Canyon of the Colorádo, Arizona, with notes on the petrographic character of the lavas, by Joseph P. Iddings: U. S. Geol. Survey Fourteenth Ann. Rept. for 1892–93, pt. 2, pp. 497–519 (Walcott) and 520–524 (Iddings), 1894.

———— Algonkian rocks of the Grand Canyon of the Colorado: Jour. Geology, vol. 3, No. 3, pp. 312–330, 1895.

ACKNOWLEDGMENTS.

In 1901 Mr. Charles D. Walcott and Mr. G. K. Gilbert spent several days at Bass Camp and on Shinumo Creek and worked out the structure of the pre-Cambrian sediments, which Mr. Walcott correlated with the section described by him in Unkar Valley. His notes, however, are unpublished, and it is due to his kindness and courtesy that the writer is enabled to present the first description of the area. To Mr. Walcott the writer is also indebted for the identification of Cambrian fossils, for a list of the Cambrian fossils found in the region, and for assistance in interpreting the stratigraphy.

To Prof. Joseph Barrell, to Prof. Charles Schuchert, and to Prof. Louis V. Pirsson, all of Yale University, the most sincere thanks are due for continued interest and advice during all stages of the work.

PHYSIOGRAPHY OF THE GRAND CANYON DISTRICT.

The great physiographic province of which the Shinumo quadrangle is a part is known as the Colorado Plateau. It is a region of nearly horizontal strata, and most of its surface lies a mile or more above sea level. The strata are beds of sandstone, shale, and limestone, which show by their character and the marine fossils they contain that they accumulated as sediments beneath the sea. It is therefore clear that after the beds were deposited and consolidated into rock they were lifted high above sea level to form the present plateau, and that the uplift was equal and general over the whole region, for the beds retain very nearly the horizontal attitude that they originally had on the sea bottom. As the strata are prevailingly horizontal, the region is preeminently a land of mesa scenery—of broad, level or slightly tilted platforms which stretch evenly away for miles, rising to younger or dropping to older formations of rock by lines of cliff; a land of encanyoned valleys whose walls descend by steps and ledges; of long, even sky line, the sweep of which is broken here and there by one or more isolated mountain masses of volcanic rock or by fantastic buttes and mesas that suggest ruined masonry. The higher portions of the region are comparatively moist and are heavily wooded with forests of [illegible]; the middle altitudes are semiarid and are [illegible] growth of juniper and pinyon; the [illegible]

faces of which either take the color of the underlying rock or are gray with the desert brush. The scenery is, above all, orderly and symmetrical, for through every land form except the volcanoes run continuous parallel layers of level strata, and each cliff shows in all its parts similar vertical profiles.

In few other regions are the topography and scenery so closely related to the character and structure of the underlying rocks. Every platform is the summit of a resistant stratum; each cliff is its edge. The gentler slopes are on the edges of weaker strata.

Nowhere else are geologic relations revealed on so vast a scale and yet so clearly, for any departure from the horizontal structure appears with startling distinctness. A great fault traversing the plateau may be expressed by a line of cliffs many miles in length; the slightest break in the beds in the walls of a canyon at once catches the eye; and the sweep of a great fold or monocline may dominate an entire landscape. The walls of the deep canyons cut by the larger streams display great natural geologic vertical and cross sections; the mountains are masses of volcanic rock which either have been poured out upon the surface of the plateau or have cut into and domed the strata. The arid climate tends to keep rock surfaces bare of soil and cliff profiles sharp and fresh, and the clear air extends the range of vision over vast distances. The prevailing aridity of the region and the impassability of the steep-walled canyons that traverse it have kept large areas untouched by civilization to the present day. In the past its lonely canyons were the home of the cliff dwellers. To-day it is the refuge of tribes of Indians who still retain their primitive customs. The natural conditions thus described make the Colorado Plateau the most fascinating region in the world for geologic study.

The southwestern part of the Plateau province, marked off by certain structural and topographic features, is the Grand Canyon district. This district has long been known through the writings of Newberry, Ives, Gilbert, Powell, and Dutton; and the work of these geologic explorers, combined with the later studies of Walcott, Davis, Robinson, Huntington, and Johnson, has given rise to a voluminous literature and has made it a classic region for geologists.

The Grand Canyon district lies in northwestern Arizona and coincides with a local uplift, or structural swell, in the Colorado Plateau. Its area is about 16,000 square miles and over practically all of this nearly level expanse one geologic formation, the Kaibab limestone, is the surface rock. This great platform is abruptly elevated above the Basin region that lies west of it by a sharp break (or fault) in the earth's crust, on the east side of which the strata stand at an elevation several thousand feet higher than the same strata on the west side. Along the eastern border of the district a sharp downward

A. GRANITE GORGE NEAR CABLE CROSSING.

Showing open gorge due to the presence of weak and easily eroded strata of the Unkar group. Cable crossing is at the narrowest point on the river, in the center of the view.

B. GRANITE GORGE ABOVE CABLE CROSSING.

Showing somber, V-shaped profile of the gorge where the massive, resistant Vishnu schist forms its walls and no weak stratified rock is present.

VIEWS UP COLORADO RIVER NEAR CABLE CROSSING.

bend, known as a monocline, carries the beds to a lower level, where they resume their nearly horizontal attitude and continue eastward beneath the higher strata of the Colorado Plateau. The upturned edges of these higher strata face the district as Echo Cliffs. On the north the district is walled in by another line of cliffs and terraces, running east and west along the southern border of Utah. These have been carved by erosion out of the higher strata of the Colorado Plateau and rise in huge steps northward to elevations of 11,000 feet or more. The southern border of the district is marked by an abrupt descent to lower country along a series of cliffs carved from the plateau strata.

The northern portion of the Grand Canyon district is divided into five minor platforms or plateau blocks by great lines of fracture or flexure, which trend north and south and are roughly parallel. The fractures are represented in the topography by cliffs and the flexures by steep slopes, so that the blocked plateaus are sharply separated from one another. The westernmost plateau, the Shivwits, is the lowest; its surface lies about 6,000 feet above the sea. Next in order toward the east are the Uinkaret, Kanab, and Kaibab plateaus, each elevated about 1,000 feet above its western neighbor by a fault. Most of the Kaibab Plateau lies above an altitude of 8,500 feet. East of the Kaibab is the fifth plateau, the Marble platform, which has been dropped 2,500 feet below the Kaibab by an eastward-dipping flexure.

Colorado River crosses the plateau province from northeast to southwest. It has carved a series of canyons whose total length exceeds 500 miles. All these canyons are clear-cut deep gashes in nearly level platforms, and their steplike walls descend abruptly by alternations of bold cliffs and narrow ledges. The river at the bottom (Pl. III) carries the drainage from the whole western front of the Rocky Mountains in Colorado and southwestern Wyoming. It is swift and turbulent and in many places flows between sheer walls. Because of the general impassability and the inhospitable character of the bordering deserts, these canyons form a barrier to human travel more effective than the Rocky Mountains. The Colorado is unbridged for 700 miles, a distance about equal to that directly between New York and Chicago.

In the high blocked plateaus of the Grand Canyon district the canyons reach their culmination in size and grandeur. The pathway of the river across these plateaus is the most remarkable valley in the world. The section that traverses the Marble platform is known as the Marble Canyon; it is 60 miles in length. The part cut through the Kaibab, Kanab, Uinkaret, and Shivwits plateaus is the Grand Canyon. The Grand Canyon is about 220 miles long and averages a mile in depth and about 10 miles in width, from rim to rim. The

Kaibab division is 50 miles in length, the Kanab 50 miles, the Uinkaret 25 miles, and the Shivwits 75 miles.

The lines of displacement that bound the plateau blocks die out in the area south of the Grand Canyon in the part of the Grand Canyon district that is known as the San Francisco Plateau. The high part of the San Francisco Plateau lying just south of the Grand Canyon is called the Coconino Plateau.

The south end of the Kaibab Plateau stands 2,000 feet above the Kanab Plateau, which lies southwest of it, and the San Francisco Plateau, which lies south of it, but it has attained this higher elevation by a gentle tilting of the earth's crust instead of by a fault or monocline. The strata around the south end of Kaibab Plateau descend very gently toward the south and southwest until they reach the level of the Kanab and San Francisco plateaus.

The Kaibab division of the Grand Canyon is cut through the highest land and is the deepest part of the canyon. Here the walls are intricately carved by erosion, and here the visitor finds that wealth of fantastic architectural detail for which the canyon is noted. This division is a relatively wide valley, which presents to the observer not a deep and gloomy gorge, but a vast, bright, open expanse. In the depths of the canyon near the base of the series of horizontal Paleozoic rocks there is a wide shelf, known as the Tonto platform, or "lower plateau" (Pl. V). A trail known as the Tonto trail runs along the Tonto platform throughout the Kaibab division. The river has cut through this platform below the base of the Paleozoic rocks into the Archean rocks, on which it flows in a V-shaped gorge whose walls descend by a steep, unbroken slope that contrasts strikingly with the steplike profile of the walls in the Paleozoic rocks above. This gorge in the bottom of the canyon is known as the Granite Gorge. (See Pls. III, V, and VIII, *B*, p. 28.)

The Kaibab division does not lie in the highest part of the Kaibab Plateau; it crosses, rather, the higher part of the inclined plane that bounds the Kaibab uplift on the south, in a direction nearly at right angles to the dip of the strata. Consequently the position of the canyon with respect to the bordering lands in this division is a peculiar one for a river valley. The Kaibab Plateau, which lies north of the canyon, slopes gradually toward the rim, and the Coconino Plateau, which lies south of the canyon, slopes gradually away from the rim, so that the canyon is a huge trench dug along a hillside.

The three divisions of the canyon west of the Kaibab are cut through lower plateaus and are not so deep as the Kaibab division. The scenery is no less imposing but is very different. In the upper part of the wall there is a platform, several miles wide, named by Dutton the Esplanade (Pl. VI), in which the main canyon is cut in a sharp gorge that has nearly vertical walls. This inner gorge is far

.B.

fault may be seen in Muav Canyon in the flexed beds of
vard into the saddle directly toward the observer.

ADO RIVER.

narrower in proportion to its depth than any part of the Kaibab division and corresponds more nearly to the popular idea of a canyon. Its walls are not greatly carved by erosion, and its scenic effect is somber and grand rather than bright and fantastic. The Kanab division shows best this somber type of scenery. In the Uinkaret division floods of lava have been poured over the walls from a great volcanic center on the Uinkaret Plateau and have reached the river. The Shivwits is the only division west of the Kaibab in which the river has cut beneath the base of the Paleozoic rocks.

The surface of the southern or Coconino Plateau slopes to the southwest, away from the canyon rim, at the rate of about 100 feet to the mile. The drainage of the plateau surface is carried in a series of shallow, open-floored valleys which have gently sloping sides, and contain no living streams. These valleys trend southwestward from the canyon rim as a consequence of the general slope of the plateau surface in that direction and drain into the broad, shallow synclinal basin occupied by Cataract Canyon. By the slow wearing back of its steep southern wall the Grand Canyon has encroached on the heads of many of these streamways, so that their truncated valleys appear along the rim as shallow notches. So general is this phenomenon that the stranger who loses his way on the Coconino Plateau has only to keep in mind the fact that if he will follow any main valley far enough headward he will come out upon the rim of the Grand Canyon.

The surface of the northern or Kaibab Plateau likewise slopes gently to the southwest and is covered with a similar system of southwestward-trending valleys. The drainage system of the Kaibab, however, runs directly into the Grand Canyon instead of away from it. Neither plateau bears a living stream.

Powell Plateau (Pl. IV, *A*) may be regarded as a disjoined part of the Kaibab Plateau. It formed on beds that lie at the same horizon in the Kaibab limestone as the Kaibab Plateau but slopes more steeply to the southwest than the Kaibab or the Coconino, its grade being about 200 feet to the mile. Powell Plateau is really a great butte, surrounded on three sides by mile-deep canyons and isolated from the Kaibab Plateau by erosion in the line of the West Kaibab fault. A narrow isthmus, notched 800 feet below the surface of the plateaus in the line of the fault, connects Powell Plateau with the Kaibab. This isthmus or gap, which is known as the Muav Saddle, forms a sharp divide that separates Muav Canyon from a lateral gorge of Tapeats Amphitheater on the north. The trail up the northern wall of the Grand Canyon divides in Muav Saddle, one branch leading to the Powell Plateau and another to the Kaibab Plateau.

In many places along the north wall of the Grand Canyon the deep side gorges of the great amphitheaters have encroached upon the valley system of the Kaibab Plateau in the same way in which the south wall of the Grand Canyon has beheaded the streamways of the Coconino Plateau. Along the eastern edge of Powell Plateau several of these shallow valleys are truncated headward by the southern wall of Muav Canyon and the same phenomenon may be noted at other places, as along the eastern edge of the Rainbow Plateau, a promontory of the Kaibab Plateau. These beheaded valleys of the Rainbow Plateau illustrate a phenomenon which is described by Dutton[1] as characteristic of other parts of the Kaibab wall east of the Shinumo quadrangle: "We often find an old ravine suddenly cut off on the brink of the abyss, and the continuation of the same ravine upon the other side of the amphitheater." In some places where the capture of a ravine is imminent, but not yet accomplished, the ravine will run along for a considerable distance parallel to the rim of the Grand Canyon and so near to it that one may stand in the bottom of the ravine and hurl a stone over the narrow divide that separates it from the great gorge. Examples are Dutton Canyon, on Powell Plateau; Saffron Valley, on the Kaibab; and the long ravine that lies east of Crescent Ridge and runs for 3 miles parallel to the rim of Shinumo Amphitheater.

The Shinumo quadrangle is on the southwest border of the Kaibab uplift and shows the transition from the Kaibab to the Kanab division of the Grand Canyon. In all the region north of the quadrangle the western boundary of the Kaibab Plateau is the West Kaibab fault, which throws the strata downward to the west and forms an abrupt topographic break. This great displacement runs into the Shinumo quadrangle, but it has here become so changed in character that it affects the strata only locally; in the greater part of its course across the quadrangle its usual westward throw is reversed, the strata being dropped on its east side. West of the Kaibab Plateau the drop is accomplished, not by a fault but by a warping of the strata. Throughout the quadrangle the Paleozoic strata dip southwestward away from the highest part of the Kaibab uplift, at a rate varying from 100 to 200 feet to the mile. This dip is well shown by the corresponding southwestward slope of the plateau surfaces, all of which accord with the rock structure. A zone of maximum warping, about 5 miles in width, runs diagonally across the quadrangle from northwest to southeast, carrying the strata downward to the southwest at the rate of 200 feet to the mile. Elsewhere in the quadrangle the dip is about 100 feet to the mile. This zone of maximum warping is shown by the surface of Powell Plateau, which drops 1,000 feet from Dutton Point at its eastern end to Ives Point at its western end.

[1] Dutton, C. E., op. cit., p. 170.

TONTO PLATFORM: VIEW EASTWARD UP KAIBAB DIVISION OF GRAND CANYON FROM LEVEL OF THE ESPLANADE DIRECTLY UNDER HAVASUPAI POINT.

PS, End of Point Sublime; *MA*, Monadnock Amphitheater; *V*, Vishnu schist; *U*, Unkar group; *T*, Tapeats sandstone; *BA*, Brignt Angel shale; *M*, Muav limestone; *R*, Redwall limestone; *Ss*, sandstone of Supai formation; *Ssh*, shale of Supai formation; *C*, Coconino sandstone. Photograph by N. W. Carkhuff.

THE ESPLANADE; VIEW NORTHWESTWARD THROUGH THE GRAND CANYON FROM HAVASUPAI POINT.

Powell Plateau; *IG*, Inner Gorge of Colorado River; *Ss*, sandstone of Supai formation; *Ssh*, shale of Supai formation; *C*, Coconino sandstone; *K*, Kaibab limestone. Photograph by N. W. Carkhuff.

Colorado River begins to flow across the zone of maximum warping at the mouth of Shinumo Creek. This point therefore marks the west end of the Kaibab division of the canyon.

TOPOGRAPHY OF THE SHINUMO QUADRANGLE.

In the Shinumo quadrangle the surfaces of the plateaus through which the Grand Canyon is trenched are developed on the highest Paleozoic formation occurring in the canyon wall—the Kaibab limestone—the Mesozoic and Tertiary formations having been eroded back to the terraces of southern Utah.

Within the Shinumo quadrangle the profile of the wall of the Grand Canyon changes from that which is characteristic of the Kaibab division to that which is characteristic of the Kanab. The most accessible outlook from which to view this scenic change is the end of Havasupai Point (Pl. VII, *B*), the longest promontory that runs out from the southern wall of the Grand Canyon. To the east is a vista of 40 miles through the characteristic scenery of the Kaibab division (See Pl. V.) The walls are greatly dissected, particularly on the northern side; great amphitheaters, filled with fantastic buttes and temples and trenched with innumerable side gorges run far back into the walls. The profile of the wall is especially distinctive; the edges of the Paleozoic strata descend abruptly through a series of cliffs, steep slopes, and narrow ledges to the Tonto platform, 3,000 feet below the rim of the canyon, and within the Tonto platform is the Granite Gorge.

On turning westward the spectator beholds a striking change. (See Pl. VI.) Directly below him, about 1,000 feet beneath the rim, a great flat-topped spur of red sandstone of the Supai formation runs far out into the canyon. Farther west more and more of these spurs appear, each capped with a similar platform, which everywhere lies upon the same layers of red sandstone. Gradually the platform widens and becomes a broad expanse of red rock, which is covered with patches of scanty soil and dotted with scrubby trees—juniper and piñón. The buttes and temples disappear; the walls are much less dissected by side gorges and extend along the canyon's sides in solemn palisades. The profile of the canyon wall is simpler, consisting of a wide outer valley whose floor is the great red platform, or Esplanade, and a deep inner canyon. The wall of the inner canyon is stupendous, the edges of the Tonto, Redwall, and Supai strata appearing almost as a single cliff 3,000 feet in height. The long red spurs of the Esplanade platform (Pl. VII, *A*) form a strange and impressive feature of the landscape and attract the attention as strongly as do the buttes and temples of the Kaibab division. Many of them have been named: Drummond Plateau, Grand Scenic Divide, Huxley Terrace, and Spencer Terrace, on the south side of

the river; Masonic Temple, Marcos, De Vaca, Tobar, Alarcon, and Garces terraces, on the north side.

The profile of the canyon wall in the central part of the Shinumo quadrangle is a combination of two types of topography, for both the Esplanade and Tonto platforms are present, separated vertically by over 2,000 feet. This feature is well seen in the wall of Shinumo Amphitheater, directly opposite Havasupai Point.

The canyon wall is more deeply dissected in the Kaibab division than in the Kanab division, the transition taking place in the Shinumo quadrangle. The dissection not only diminishes from east to west but also differs strikingly in amount in the opposite walls of the canyon in the two divisions. In the Kanab division, beyond the western border of the Shinumo quadrangle, the river flows in the very center of the canyon and the northern wall is no more dissected than the southern wall, but in the Kaibab division the north rim lies three times as far back from the river as the south rim; the great amphitheaters and their limiting promontories, which extend far into the canyon, the buttes and temples, and the deep lateral gorges all belong to the north side of the canyon. The south wall presents a simpler aspect; few of the side gorges extend back into the rim of the canyon, there are few buttes and outliers, and the great amphitheaters are wholly lacking. When compared with that of the fantastic topography of the north side, the scenic effect of the precipitous south wall is somber.

The variations in the amount of dissection of the canyon wall depend upon climatic and structural conditions, whereas the change from east to west in the profile of the wall is explained by certain variations in the thickness and character of the Paleozoic strata. The origin of these topographic features will be discussed elsewhere in this report after the conditions upon which they depend have been described.

The Colorado maintains its general northwesterly course through the Kaibab division into the Shinumo quadrangle as far as the mouth of Shinumo Creek, where it bends westward and flows across the zone of warping that marks the boundary of the Kaibab uplift. Swinging in two great loops, first to the south and then to the west, it doubles back again and flows northeastward around Powell Plateau, passing thence beyond the northern boundary of the quadrangle. Several miles beyond the northern boundary of the quadrangle Tapeats Creek enters the river from the east, draining a great amphitheater of the same name which lies north of Powell Plateau. At the mouth of Tapeats Creek the river bends to the southwest and maintains a southwestward course for 40 miles through the Kanab Plateau, nearly the entire length of the Kanab division.

A. VIEW NORTHWARD FROM BASS CAMP, SHOWING MOUNT HUETHAWALI, A BUTTE ON THE ESPLANADE (AT THE LEFT) AND HUXLEY TERRACE, A DISSECTED SPUR OF THE ESPLANADE.

Mount Huethawali was once part of a great promontory of the Coconino Plateau but has been isolated by erosion. Its summit is composed of two formations of rock that are very resistant to erosion, the Kaibab limestone and the Coconino sandstone. These make a cap that prevents the soft shales of the Supai formation, which are in the lower part of the butte, from wasting rapidly away. As time goes on the cap will dwindle to a mere knob, like that which surmounts Holy Grail Temple; finally it will disappear entirely, and the soft shales beneath, being no longer protected, will be removed from the floor of the Esplanade. This view, which was taken after an exceptionally heavy fall of snow, shows about the maximum extension of the snow line downward into the Canyon in winter.

B. VIEW EASTWARD FROM THE SUMMIT OF MOUNT HUETHAWALI, SHOWING FOSSIL MOUNTAIN AND HAVASUPAI POINT.

The cirque in the foreground is the head of Bass Canyon, down which Bass trail descends to Colorado River. The peaklike promontory in the center of the view is Fossil Mountain, which is gradually being isolated from the Coconino Plateau by erosion and will in time become a butte or outlier like Mount Huethawali. The same fate, though it is more remote, awaits Havasupai Point, the high promontory at the left of Fossil Mountain.

The general course of the great gorge itself is not affected by the smaller bends of the river and may be considered simply as northwesterly through the Kaibab division and beyond, to the mouth of Tapeats Creek, and thence southwesterly through the Kanab division.

The Granite Gorge, which forms the interior of the canyon through the Kaibab division, is not continuous in the Shinumo quadrangle west of the mouth of Garnet Canyon, because of changes in the course of Colorado River with reference to the rock structure. Thus the bend westward and southward at the mouth of the Shinumo causes the river to flow in the direction of the dip of the Paleozoic strata, and as the dip is greater than the grade of the stream the river bed is gradually carried out of the Archean rocks into the basal sandstone of the Tonto group, which terminates the Granite Gorge a short distance below the mouth of Garnet Canyon. Through Stephen Aisle and Conquistador Aisle the bed of the river is in the Paleozoic strata. Beyond the end of Alarcon Terrace the river bends and again flows northeastward, taking a course that soon carries the bed back into the Archean rocks, so that the Granite Gorge reappears in this part of the canyon, continuing until the river finally turns southwestward, at the mouth of Tapeats Creek. This section is called the Lower Granite Gorge. In all the Kanab division west of the mouth of Tapeats Creek the river flows in Paleozoic strata.

The actual length of the course of the Colorado across the quadrangle, measured along the surface of the stream, is 31½ miles. The mean elevation of the surface of the river where it enters the quadrangle on the east is 2,285 feet; where it leaves the quadrangle on the north, 2,035 feet. The total descent of the river within the quadrangle is therefore 250 feet, and the average declivity is 7.9 feet to the mile. The declivity, however, is not uniform. East of the mouth of Garnet Canyon it is 10 feet to the mile; west of this point it is 6.2 feet to the mile. The difference is explained by the fact that above Garnet Canyon the river flows upon resistant Archean rocks, whereas below Garnet Canyon it flows chiefly upon less resistant sedimentary rocks. At the Cable Crossing the width of the river is 300 feet, its depth is 50 feet, and its average rise at times of high water is 40 feet.

The only living tributary of the Colorado in the quadrangle is Shinumo Creek (Pl. XIV, *A*, p. 55), the master stream that drains Shinumo Amphitheater, of the north wall. It is of the same size and kind as Bright Angel Creek, 20 miles to the east, and its clear water presents a striking contrast to the muddy torrent of the Colorado. The length of Shinumo Creek from its source at Big Spring, on the rim of the Kaibab, to its confluence with the Colorado is 12 miles, and in this distance it falls 5,400 feet, its average declivity being 450 feet to the mile.

The topography of Shinumo Amphitheater, besides presenting an equal development of both the Esplanade and Tonto platforms, is remarkable in another way. In the other great amphitheaters of the Kaibab division the master gorges trend southwestward, the tributary gorges trend in the same general direction, and lateral gorges perpendicular to the main axes of the amphitheaters are of minor development. In Shinumo Amphitheater the lateral gorges have become dominant features, so that the main axis of the amphitheater trends northwestward, lying at right angles to the course of the master stream and parallel to the course of the Colorado. The greatest lateral gorge extends entirely across Shinumo Amphitheater from Point Sublime on the southeast to the Muav Saddle on the northwest. Only a mile of this lateral gorge is occupied by the master stream of Shinumo Amphitheater; the remainder is occupied by two small intermittent streams. The western part of the gorge, which extends from the Muav Saddle to Shinumo Creek, is drained by Muav Creek and White Creek and is called Muav Canyon; the eastern part, extending from Shinumo Creek to Point Sublime, is drained by Flint Creek and has no local name. The entire lateral gorge will be referred to as the "Muav-Flint Canyon." This remarkable rectilinear depression is situated upon the line of the West Kaibab fault. Two smaller lateral gorges cross the heart of the amphitheater parallel to the Muav-Flint Canyon; these are situated upon minor lines of fracture.

The course of Shinumo Creek through the canyons of Shinumo Amphitheater everywhere lies in one of two main lines which are perpendicular to each other. The course in the northeast-southwest line, which carries the stream onward toward its junction with the Colorado, is consequent upon the dip of the Paleozoic rocks; the course in the northwest-southeast line, which holds the stream in the lateral gorges, is controlled by the West Kaibab faults and by fracture lines. (See pp. 75–80.)

The highest point in the Shinumo quadrangle is the surface of the Kaibab Plateau in the northeast corner of the quadrangle, where the elevation is 8,450 feet; the lowest point is the bed of the Colorado River, at the place where it flows beyond the northern boundary of the quadrangle, where the elevation is about 2,000 feet. As the surfaces of the plateaus and of the platforms within the canyon are everywhere accordant with the rock structure, the altitudes of these surfaces diminish progressively toward the southwest in all parts of the quadrangle in conformity with the dip of the Paleozoic rocks.

For example, the elevation of the Kaibab Plateau at the head of Shinumo Amphitheater is 8,000 feet; but at Point Sublime, 5 miles south, it is only 7,500 feet. Farther southwest, on the opposite side of the Grand Canyon, at Havasupai Point, the Coconino Plateau

stands at 6,750 feet; 10 miles farther southwest it stands at 5,900 feet. At the head of Shinumo Amphitheater the elevation of the Esplanade, a platform within the canyon, is 6,750 feet; at Holy Grail Temple, in the center of the amphitheater, it is 6,100 feet; farther southwest, across the river, at Darwin Plateau, it is 5,400 feet, and in Aztec Amphitheater it is 5,000 feet. The Tonto platform stands at 3,750 feet under Dox Castle; directly opposite, on the south side of the river under Tyndall Dome, its altitude is 3,300 feet.

The wall of the Grand Canyon drops most abruptly at Dutton Point (Pl. XVIII, p. 86), where it descends 5,355 feet from Powell Plateau to the river in 3 miles; and at Havasupai Point, where it descends 4,500 feet in a mile and a half, presenting the most precipitous descent in the Grand Canyon.

The greatest width of the Grand Canyon in the quadrangle is in the stretch from the head of Aztec Amphitheater to the head of Shinumo Amphitheater, a distance of 16 miles. The narrowest point is between Apache Point and Ives Point, 4¾ miles. Even at this narrowest point the width is over five times the depth.

CLIMATE.

The climatic differences within the Shinumo quadrangle are remarkable. The range in climate between the Kaibab Plateau and the bottom of the canyon is as great as that between the mountains of Colorado and the Mojave Desert. The winters on the Kaibab Plateau are extremely severe; from November to April the snow lies deep in the woods, in places accumulating to a depth of 10 feet. Even in midsummer the nights are chilly and the days are delightfully cool. Within the canyon, however, snow rarely falls below the level of the Esplanade, and on the Tonto platform a fall of snow is practically unknown. In the depths of the canyon the winters are mild and freezing temperatures are rare. From April to October, whenever the days are cloudless, the entire interior of the canyon concentrates the solar heat and becomes a veritable oven. All day the bare rocks absorb the heat of the sun, becoming so hot as to burn the hand; by afternoon the wind is like a furnace blast, and the rocks continue to radiate their heat long after dark. The summer heat is tempered greatly on the cloudy days during the period of rains. The climate of the southern or Coconino Plateau at Bass Camp is characterized by more open winters as well as by warmer summers than the Kaibab. Snow rarely accumulates on the surface to a great depth and as a rule vanishes entirely within three days after a storm; and in summer many days are unpleasantly hot.

The climate of the Kaibab Plateau is decidedly moist, the precipitation being probably twice as great as that received upon the Coconino Plateau, across the canyon. This difference is due chiefly to the greater altitude of the Kaibab Plateau. In winter the precipi-

tation on the Kaibab takes the form of snow; in summer it comes in thundershowers which occur during the afternoon and evening. Looking across the canyon from Bass Camp on the south rim on almost any summer evening one may see storm after storm sweeping over the surface of the Kaibab Plateau, most of them accompanied by violent electrical display, while the sky overhead and to the west over the Kanab Desert remains as clear as crystal. Another factor that contributes to the greater rainfall of the Kaibab seems to be the presence of the Grand Canyon itself. Every general winter storm that visits both sides of the canyon alike is followed on the south rim by a day of clearing; but the clouds that rise out of the canyon after the storm sweep back over the north wall and reprecipitate on the surface of the Kaibab. Few of these secondary storms return over the south rim. The climate of the Coconino Plateau in the quadrangle is semiarid; in spring and early summer no rain may fall for a month. The precipitation is greatest in winter and in the months of July, August, and September. Much of the rain that falls within the canyon evaporates before it reaches its lower part, which is therefore more arid than the Coconino Plateau.

Powell Plateau (Pl. IV, A, p. 18), whose higher eastern portion stands at the same altitude as the Kaibab rim and whose lower western portion stands at the altitude of the Coconino, has a climate that is intermediate between those of these two divisions. Its situation in the canyon, where it forms an island, serves to moderate the cold in winter, for the warm air which rises out of the deep canyons that surround it acts as a radiator; snow does not accumulate so deep on its eastern end as on the Kaibab, and on its western end does not accumulate at all. It is a resort in winter for game and cattle that are driven out of the Kaibab by snow. Its higher eastern end receives abundant rainfall, whereas its lower western end is semiarid. Owing to its exposed position it is at all times of the year subject to violent gales of wind.

The variation in the amount of rainfall with difference in altitude is the chief cause of the variations in the degree of dissection of the canyon walls. The plateaus on both sides of the canyon in the Kaibab division are much higher than those in the Kanab division, where the rainfall is therefore much greater and the forces of erosion more active, and the walls are consequently far more dissected in the Kaibab than in the Kanab division. The much greater dissection of the northern than of the southern wall of the canyon in the Kaibab division may be similarly explained, the higher altitude of the northern wall giving it much greater rainfall than the southern wall.

In this dissection the rock structure is also important. Since the surface of the Kaibab Plateau slopes toward the rim of the canyon, all the surface water within a radius of many miles finds its way into the canyon over the northern wall. Even the water that sinks under-

ground—which far exceeds the surface water in quantity because of the system of caves, sink holes, and underground drainage channels with which the Kaibab limestone is honeycombed—eventually finds its way southwestward along the dip of the strata and reappears as springs in the northern wall of the Grand Canyon, feeding the tributary streams of the Colorado and increasing the activity of the forces of erosion on that side of the river.

The waters of the semiarid Coconino Plateau, on the contrary, both surface and underground, are carried directly away from the Grand Canyon by the slope of the surface and by the southwesterly dip of the strata; consequently the forces of erosion are less active in the southern wall of the canyon.

VEGETATION.

The variation in the flora in the Shinumo quadrangle is as great as that in the climate. The surface of the Kaibab Plateau is covered with a magnificent open forest of yellow pine; the trees grow large and far apart and the ground is free from undergrowth, so that the plateau has the aspect of a great park. Englemann spruce grows on the north slopes of the washes, and cottonwood, aspen, and scrub oak in their bottoms. A minor flora of flowering plants exceedingly rich in species covers the floor of the forest. The flora of the Coconino Plateau in the quadrangle differs completely from that of the Kaibab. The surface is covered with a dwarf forest of gnarled juniper, piñón, and "mountain mahogany" (*Cercocarpus ledifolius*); the little trees grow wide apart and the open stretches are covered with sagebrush and "Mormon tea," with occasional cactus, "mescal," and other plants of the century family.

This difference between the floras of the two plateaus is due to differences in precipitation and temperature, which vary directly with the altitude, and for this reason the floras of the plateaus furnish an almost unfailing index of their elevation, a fact that is strikingly shown on the southwestward-sloping surface of Powell Plateau. The whole eastern half of this plateau lies at an elevation of 7,000 to 7,500 feet and is covered with the open pine forest characteristic of the Kaibab, but at an elevation of about 7,000 feet the flora changes, passing into the dwarf forest of juniper and piñón that characterizes the southern plateau across the canyon.

In the region farther east, beyond the border of the Shinumo quadrangle, the Coconino Plateau attains a much greater altitude and the flora there becomes more like that of the Kaibab Plateau.

Within the canyon itself the variation in the flora is just as great, and is again an index of the elevation.

The flora of the Esplanade platform, a thousand feet below the south rim, consists of stunted juniper and piñón with *Coleogyne ramosissima* (locally known as "greasewood") as the predominant

bush in place of the sagebrush of the Coconino Plateau. Cacti and plants of the century family are more abundant than on the plateau, but less abundant and smaller than in the bottom of the canyon, a condition due to the fact that the Esplanade level is within reach of the winter snows and frosts. On the north side of the canyon, where the elevation of the Esplanade is much greater than on the south side, mountain mahogany, manzanita, live oak, and other dwarf trees appear in the flora, making a thick chaparral that cloaks all the slopes with a dense mantle of green.

The flora of the Tonto platform, 3,000 feet below the south rim, and of all the interior of the canyon below the Red Wall is the flora of a hot and arid desert. The dominant plants are *Coleogyne ramosissima*, "Mormon tea," and other small gray perennial shrubs of various species, each plant standing apart by itself in the formal manner characteristic of desert vegetation. Cacti, aloes or agaves, and yuccas here attain their densest growth and greatest size, the cacti being particularly rich in species. Every plant in the flora is either prickly or aromatic, leaf surfaces are reduced to a minimum, devices for storing water attain the greatest perfection, and the dominant color is a dull gray. The somber colors and the reduction of leaf surfaces are likely to deceive the observer both in regard to the richness of the flora in species and the abundance of plant life, which is far greater than one would suspect. Small trees of *Acacia greggi*, or "cat claw," and here and there a few of *Cercis occidentalis*, or "red bud," grow in the beds of washes that contain living or intermittent streams.

The vegetation in the bottoms of the canyons of the north side of Shinumo Amphitheater that contain living streams is beautiful beyond description and affords a refreshing contrast to the desert flora of the Tonto platform. Tall cottonwoods grow in the lower canyons, maiden-hair ferns hang on the walls in shady places, thickets of willow border the streams, and grass grows on the banks where there is soil. Higher up in the canyons, oaks, maples, and other deciduous trees grow, and in some places there are beds of tall rushes. The most characteristic bush of these upper north-side canyons is the manzanita, which apparently does not grow on the south side of the Grand Canyon in the quadrangle.

INDIAN RUINS.

Evidences of former human occupation are found everywhere in the Grand Canyon region and the observant traveler will see them in many places in the Shinumo quadrangle, but as few of these ruins are well preserved he must not expect to see anything so spectacular as the wonderful ruins of the Mesa Verde in southwestern Colorado or the Canyon De Chelly in northeastern Arizona. Ruins are most numerous in the canyons of Shinumo Amphitheater and consist of

A. EAST WALL OF CANYON OF SHINUMO CREEK NEAR SHINUMO GARDEN.

B. VIEW EASTWARD UP COLORADO RIVER FROM A POINT NEAR THE MOUTH OF BASS CANYON, SHOWING GRANITE GORGE.

the fallen and crumbled walls of rude stone houses. Some of these ruins are perched high under overhanging ledges which still show the blackening of smoke; others lie among huge blocks of débris that have fallen from the cliffs; still others stand in the open, away from any natural shelter. The only well-preserved structures are tiny storehouses, built high up along the crevices in the canyon walls. Numerous relics have been found by digging in or around the ruins, among them mealing stones, mortars, pestles, corncobs, ropes of yucca fiber, arrowheads, and various stone implements. Fragments of pottery are littered about and remains of irrigation ditches are still visible in Shinumo Canyon, where gardens were cultivated. The walls of the ruins on the plateaus have crumbled to almost shapeless heaps of stone, and in some of those on Powell Plateau tall pine trees are growing. The only ruin that is at all well preserved is at the head of Bass trail, on the Coconino Plateau. It is supposed that most of these ruins are the work of the cliff dwellers, the ancestors of the present Pueblo Indians of the Southwest.

The trails into the Grand Canyon on both sides of the river follow old Indian trails. All the way down Bass trail and all the way up the trails through Shinumo and Muav canyons the traveler will see at intervals the blackened ruins of circular pits where the Indians have roasted the "mescal," a species of agave that grows everywhere in the canyon. These mescal pits are found in every canyon on the south side of the river. The Havasupai Indians, who dwell in Cataract Canyon, 25 miles southwest of Bass Camp, still make occasional use of a trail that descends to the Esplanade at Apache Point.

GEOLOGY.

AGE AND CHARACTER OF THE ROCKS.

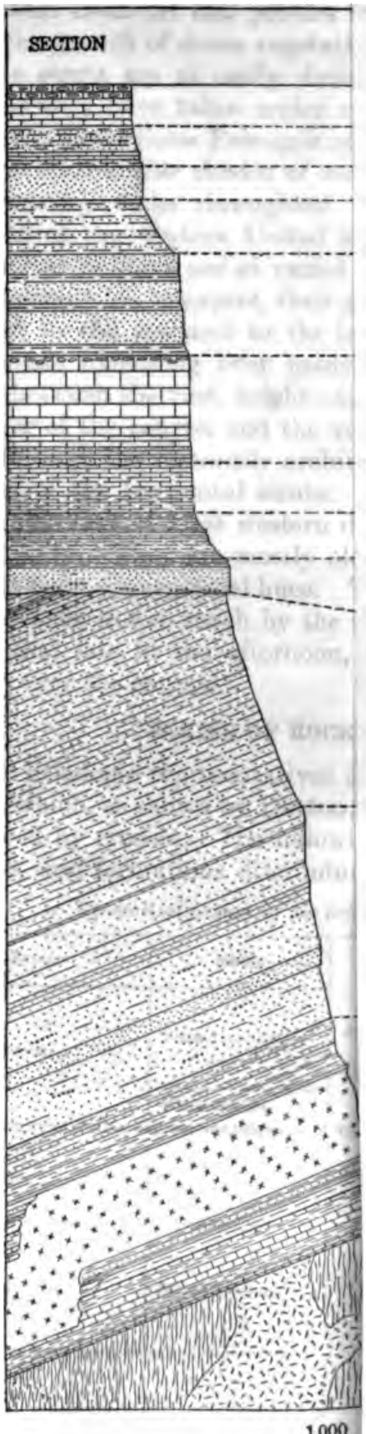
Four great systems of rock are exposed in the walls of the Grand Canyon in the Shinumo quadrangle. (See Pl. IX.) These systems represent three of the earliest eons of geologic time, the Archean and Algonkian periods and the Paleozoic era, the last being represented by the Cambrian and Carboniferous systems.

The foundation rocks of the region are crystalline schists, gneisses, and granitic rocks of Archean age. The schists and gneisses are metamorphic rocks, whose original character has been changed by pressure, so that they are gnarled and crumpled. These metamorphic rocks are known as the Vishnu schist. The granitic rocks are igneous. They invaded the metamorphic rocks in a molten state and are massive in aspect. The Archean rocks form the walls of the Granite Gorge (Pls. III, p. 16, and VIII, *B*) in the bottom of the canyon. All types of these Archean rocks are about equally resistant to erosion, and consequently they form a continuous ragged slope, which gives the walls of the Granite Gorge a V-shaped profile. In color they are dark and somber. By these features and by their lack of stratifica-

tion they may be readily distinguished from the Algonkian and Paleozoic rocks.

The Archean rocks are separated by a profound unconformity (Pls. VIII, *B*, and XVIII, p. 86) from a series of overlying sedimentary rocks, which is inset in the Archean rocks by block faulting and is of Algonkian age. The sedimentary rocks (Pls. IV, *B*, p. 18, and XI, p. 39) are as little altered as the still higher Paleozoic rocks. Unlike the Paleozoic rocks, however, they do not lie in their original horizontal position but are inclined at various angles. They comprise limestones, shales, sandstones, and intrusive masses of diabase, and are found only within the greater depths of the Grand Canyon.

The Archean and Algonkian rocks are alike separated by another profound unconformity (Pl. XVIII) from the Paleozoic rocks, consisting of limestone, shale, and sandstone. The Paleozoic rocks (Pl. XVIII) lie in a nearly horizontal position, practically as they were laid down. They form the floors of all the plateaus and the greater part of the walls of the Grand Canyon and have determined the whole character and spirit of the scenery. The huge scale and the infinite multiplication of the characteristic architectural rock forms make the scenery of the Grand Canyon seem strange and unreal, yet it is but the supreme expression of all that is most characteristic in the land sculpture of the Plateau province. The processes of earth sculpture are going on here, as in other regions, under the attacks of rain, running water, frost, and wind. The erosion is spasmodic, because of the aridity of the climate, yet it is none the less effective. Slopes are kept partly bare because the desert plants grow far apart, so that the concentrated energy of a single torrential shower wreaks more havoc here than a season's rainfall on the densely covered slopes of a humid region. But these forces are working on rocks which, as we have seen, lie in nearly level beds that are continuous over great areas. Therefore they produce everywhere forms that are nearly identical in the vertical element, or profile, though varied and irregular in plan, as might be seen on looking down on them from a balloon or examining their outlines on the map. As the beds, from top to bottom, show infinite variations in their resistance to erosion, every part of the canyon wall, every pinnacle and butte, is characterized by its own steplike alternation of cliff and terrace or slope, in delicate response to the varying character of the strata. In the canyon wall the cliffs are determined by the edges of the harder strata. Upon the plateaus the soft rocks have been washed away over miles of the country, leaving platforms whose floors are a hard stratum. As erosion goes on, parts of the plateau become separated by growing canyons or ravines and stand as solitary outliers, capped by remnants of the harder rock; these are the buttes. Finally, all these land forms, which in a moister region would soon be dulled or obscured, are kept sharp and fresh by the prevailing aridity, the effect of which is to



GENERALIZED

maintain clean-cut cliff profiles and to retard the formation of soil and the growth of dense vegetation to mantle the slopes.

The strata are as easily distinguished by their colors as by the shapes they have taken under erosion. In the color scheme of the Grand Canyon these Paleozoic rocks play the dominant part. They are of the familiar shades of red, brown, buff, and gray shown by sedimentary rocks throughout the Rocky Mountain and Plateau regions of the western United States, and although the colors are neither so brilliant nor so varied as the visitor at the Grand Canyon is commonly led to expect, their general effect is very striking. They appeal to the eye and to the imagination through the stupendous panorama extending over many miles; through the extreme contrast between the vast, bright expanse of bare rock of the unforested interior of the canyon and the verdant wooded plateaus on the rim, and through the rigorously architectural effect imparted by the wide extent of the horizontal strata. Much of the charm of the varied tints, like that of most western desert coloring, lies in their dullness and oddity. They are mostly old, subdued shades, which vary just a little from conventional hues. The most beautiful effects, however, are wrought not so much by the colors of the rocks as by the purple haze that late in the afternoon, particularly in midsummer, often hangs over the canyon.

SERIES OF ROCKS DISCRIMINATED.

The lithologic representatives of the Permian, Mesozoic, and Tertiary, which, as shown by Dutton, once covered the region, have been removed by erosion. The following table shows the systems, series, groups, and formations discriminated in the quadrangle:

Generalized section of the rocks of the Shinumo quadrangle.

System.	Series.	Group.	Formation.
Carboniferous.	Pennsylvanian.	Aubrey.	Kaibab limestone. Coconino sandstone. Supai formation.
	Mississippian.		Redwall limestone.
Unconformity of erosion without unconformity of dip.			
Cambrian.		Tonto.	Muav limestone. Bright Angel shale. Tapeats sandstone.
Great angular unconformity.			
Algonkian.	Grand Canyon.	Unkar (intruded by sills of diabase).	Dox sandstone. Shinumo quartzite. Hakatai shale. Bass limestone. Hotauta conglomerate.
Greatest angular unconformity.			
Archean.			Vishnu schist (intruded by masses of quartz diorite and by dikes of pegmatite).

The names employed in this report for the Paleozoic formations have been recently authorized by the United States Geological Survey to supplant older descriptive and duplicated names and to bring them into conformity with present usage. The following table gives equivalents of the older in the newer nomenclature.

Present nomenclature.	Former nomenclature (reports of Dutton, Gilbert, and Walcott).
Kaibab limestone	Cherty limestone.
Coconino sandstone	Cross-bedded sandstone.
Supai formation	Lower Aubrey sandstone.
Redwall limestone	Redwall limestone.
Muav limestone	Marbled (or mottled) limestone.
Bright Angel shale	Tonto shale.
Tapeats sandstone	Tonto sandstone.

PROTEROZOIC ROCKS.

ARCHEAN SYSTEM.

VISHNU SCHIST.

NAME.

The name Vishnu terrane has been given by Walcott[1] to the fundamental crystalline complex of the Grand Canyon region that underlies the unaltered sedimentary rocks of Algonkian age and is separated from them, as well as from the overlying Cambrian, by a profound unconformity. The type locality is on Colorado River, 30 miles east of the mouth of Shinumo Creek, at the base of one of the great buttes called "Vishnu's Temple," from which Walcott derived the name.

DISTRIBUTION IN THE GRAND CANYON.

In the Kaibab division the Vishnu schist is exposed continuously for more than 40 miles in the walls of the Granite Gorge (Pl. VIII, *B*). In the eastern part of the Kanab division it is exposed in Lower Granite Gorge and is probably exposed in other places in the Kanab division between the end of Lower Granite Gorge and the mouth of Kanab Creek, for Powell,[2] in his account of this portion of his journey down the river, mentions "passing for a short distance through patches of granite, like hills thrust up into the limestone." The Vishnu is exposed through the greater part of the Shivwits division and around the southwestern border of the Grand Canyon district.

OCCURRENCE AND DISTRIBUTION IN THE SHINUMO QUADRANGLE.

The length of the exposure of the Vishnu schist in the Granite Gorge along the course of the river is about 17 miles; in Lower Granite Gorge it is 4 miles. A small but interesting exposure in

[1] Walcott, C. D., Pre-Cambrian igneous rocks of the Unkar terrane, Grand Canyon of the Colorado, Arizona, with notes on the petrographic character of the lavas, by J. P. Iddings: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 497–519, 520–524, 1894.

[2] Powell, J. W., Exploration of the Colorado River of the West and its tributaries; explored in 1869, 1870, 1871, and 1872, under the direction of the Secretary of the Smithsonian Institution, p. 92, 1875.

the depths of the Muav-Flint Canyon lies on the northeast side of the West Kaibab fault and extends for 3 miles southeastward in the canyons of White, Shinumo, and Flint creeks, and for 1 mile northeastward up the canyon of Shinumo Creek.

No detailed study of the Vishnu schist was made in the Shinumo quadrangle beyond that required to locate and determine the various types represented in the area shown on the geologic map, and owing to the small extent of these exposures it was not possible to determine the general Archean structure from a study of this area alone. The rocks here are a metamorphic complex of quartz, mica, and hornblende schists and are invaded by a batholithic mass of quartz diorite and injected by veins of pegmatite and aplite. East of the Shinumo quadrangle and west of the mouth of Walthenberg Canyon in the Shinumo quadrangle the prevailing rocks are gneisses.

TYPES OF THE SCHIST.

Three main types of rock are found in the formation within the area studied:

The first type is a quartz schist that grades into mica schist. It comprises the greater part of the Vishnu schist that is exposed in the gorge of the Colorado River west of the Cable Crossing and is also exposed in the canyon of White Creek and in the canyon of Flint Creek just above its junction with Shinumo Creek.

The second type is a quartz schist that grades into quartz-hornblende schist. It is exposed chiefly in that part of the Muav-Flint Canyon that is occupied by Shinumo Creek, grading both eastward and westward into the quartz-mica schist.

The third type is a hornblende schist. It occurs in one small outcrop, about 200 feet wide, on the east side of a dry wash that joins the valley of Shinumo Creek just below the mouth of White Creek, and is sharply bounded on both sides by the quartz-mica schist.

The rocks are typically schistose. The planes of schistosity generally stand almost vertical and trend northeastward, though their direction varies from place to place. The schists are locally much twisted and contorted.

LITHOLOGY OF THE TYPES.

The less micaceous phase of the quartz-mica schist is dark greenish gray and its fresh surfaces have a satiny luster. Its cleavage is imperfect, its texture is fine grained, and it contains no visible mineral constituent except quartz. The microscope shows that it is composed almost entirely of fine interlocking grains of quartz, and some small flakes of white mica, arranged in parallel lines. The extreme quartzose phase of the schist contains very little mica—just enough to impart a satiny luster to the rock.

Freshly fractured surfaces of the micaceous phase of the schist are grayish, with either a pinkish or greenish tinge, but the weathered rock is red. This phase shows a rather distinct cleavage and a texture ranging from fine to coarse. The unaided eye can distinguish both quartz and mica in the rock, and the microscope shows that it is composed of interlocking grains of quartz and an almost equal amount of mica, the flakes of mica being arranged in parallel lines. The mica is chiefly muscovite, but includes some flakes of brown biotite.

Locally the schist is garnetiferous, and in one place tourmaline was observed. All gradations between the quartzose and the micaceous phases occur, but in no specimen does the mica exceed the quartz in quantity.

The quartz-hornblende schist is a dark-green, dense, hard rock, with imperfect cleavage and fine-grained and uniform texture. Its mineral constituents can not usually be distinguished in the hand specimen without the aid of the lens, but the microscope shows that it consists of about equal proportions of quartz and green hornblende. The quartz occurs in interlocking grains and the hornblende tends to form automorphic crystals whose longer axes are roughly parallel. No other minerals were observed in the slides examined. Some phases of the rock contain more quartz than hornblende.

The hornblende schist is a dark-green, soft, coarse-grained rock, considerably disintegrated, and crumbles under the hammer. Megascopically it consists almost entirely of dark-green hornblende and exhibits no schistosity. The microscope shows that it consists almost wholly of large crystals of green hornblende in all stages of alteration, with a small amount of interstitial quartz, the quartz granules being strung out in roughly parallel lines. The rock is much altered and a thin section of it is unsatisfactory.

ORIGIN OF THE SCHIST.

The rocks in the Shinumo area afford no clear evidence of the original character of the Vishnu schist—no evidence of banding that can be clearly referred to original sedimentary bedding and no evidence of original clastic texture—but the mineralogic composition of the quartz schists of the mica and hornblende type suggests their sedimentary origin. Either type might have resulted from the regional metamorphism of an arkose sandstone or shale.

Such rocks would become either quartz-mica or quartz-hornblende schist, the type assumed being determined by the proportion of iron in the original sediments. Certainly the great preponderance of quartz in these rocks creates a presumption against their igneous origin. The present aspect of the schists is doubtless due to processes connected with regional metamorphism, namely, subsidence and deep burial, subsequent folding and mashing, and slow recrystallization.

The original character of the hornblende schist described as occurring in a narrow outcrop between the other schists can not easily be determined. The fact that the rock consists of little else than hornblende suggests that it was originally an igneous rock of a basic type. The fact that the microscope discloses in it a schistose structure shows that it is at least earlier than the period of regional metamorphism in which the schists wherein it is inclosed assumed their present structural and mineralogic character.

AGE AND CORRELATION.

The Vishnu schist consists of rocks which, in the light of present knowledge, can be conceived to have acquired their character only at great depths beneath the earth's surface, in what is technically known as the "zone of flowage." It is therefore evident that the unconformity which separates them from the overlying Algonkian sediments of the Grand Canyon series represents a vast amount of erosion and a long period of time—a period much greater in events even than that represented by the profound unconformity which separates the succeeding Grand Canyon series from the overlying Paleozoic. The Vishnu schist is therefore assigned to the Archean system. It seems likely, as stated by Ransome,[1] that it may be correlated with the Pinal schist of the Globe and Bisbee regions, and that it presents "somewhat different aspects of the fundamental crystalline complex of Arizona."

These rocks have not yet been studied in detail in the Grand Canyon region, and their internal structural relations are unknown. A careful study of their exposures in the Kaibab division, in the Shivwits division, and along the southwestern border of the Plateau province may reveal the general Archean structure and the relation of these rocks to the fundamental complex of the southern part of Arizona.

INTRUSIVE QUARTZ DIORITE AND DIKES OF PEGMATITE ASSOCIATED WITH THE VISHNU SCHIST.

The Vishnu schist is intruded by masses of quartz diorite and by dikes of pegmatite.

QUARTZ DIORITE.

So far as observed, quartz diorite constitutes all the Archean system in the Shinumo quadrangle that is exposed in the Granite Gorge of Colorado River for half a mile east of Cable Crossing. Its western contact is well defined, but its eastern limit was not located.

The quartz diorite in the river gorge east of Cable Crossing is a coarse-grained, dense, resistant rock of typical granitic texture,

[1] Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, p. 21, 1904.

which tends to weather into roughly angular blocks and thus to assume forms that distinguish it in the mass from the Vishnu schist. It is dark gray, looks remarkably fresh, and contains visible particles of white striated feldspar, dark hornblende, and glistening black biotite. The rock is uniform in texture throughout the exposures observed, is apparently without contact modifications, and shows no gneissoid banding.

Under the microscope it is seen to be a coarse-granular rock of granitic texture. Its dominant mineral constituents are plagioclase and common hornblende, the plagioclase ranging from oligoclase to labradorite. Microcline, orthoclase, and quartz are present in about equal proportions, but their total amount does not equal that of the plagioclase. Brown biotite appears in somewhat less quantity than the hornblende, and titanite and magnetite are accessories. Occasionally the quartz is poikilitic in the orthoclase. The feldspathic and ferromagnesian minerals occur in about equal proportions. If it were not for the preponderance of plagioclase the rock might be classed as a quartz monzonite or granodiorite, but it is probably best classed as a quartz diorite with a monzonitic aspect. The microscope reveals no cataclastic structure nor other evidence of dynamic action, and the minerals are fresh and unaltered.

The origin of the quartz diorite is reasonably clear. As it is a coarse-grained igneous rock of plutonic aspect occurring over a large area, sharply cutting the Vishnu schist, and showing no textural modifications at the contact, it doubtless represents a deep-seated igneous invasion of a large mass, of the type known as a batholith. As the rock is unaltered and shows no gneissoid or cataclastic structure the batholithic invasion probably occurred after the period of regional metamorphism that produced recrystallization and schistosity in the inclosing schists. The invasion of the batholith may in itself have aided in producing this recrystallization and schistosity, but the field evidence seems to be adverse to such a conclusion, for the schist shows no change either in texture or in mineral composition with increase of distance from the contact.

PEGMATITE.

A granitic pegmatite occurs in dikes that cut all types of the Vishnu schist and that may readily be divided into two generations. The older generation is folded with the schists; the younger generation is a great network or mesh of dikes that cuts both the quartz diorite intrusive and the Vishnu schist. A vertical section covering a thousand feet exposes a huge mesh of these dikes in the wall of the Granite Gorge east of the mouth of Hotauta Canyon. (See Pl. VIII, *B*, p. 28.)

The pegmatites are pink, very coarse-grained rocks, composed chiefly of quartz and pink orthoclase, and in places contain large crystals of silvery-white mica. Most of the dikes exhibit typical

comb structure inward from their walls and a graphic arrangement of the quartz and feldspar. Along the walls of some of the dikes the texture becomes aplitic.

The older pegmatite dikes are folded intimately with the Vishnu schist. Their injection may have either preceded or accompanied the regional metamorphism. The younger pegmatite dikes cut both the Vishnu schist and the intrusive quartz diorite. Where they cut the schists they break clean across the schistosity. The injection of these dikes is the latest recorded event in the igneous activity of Archean time within the area.

ALGONKIAN SYSTEM.

GRAND CANYON SERIES.

NAME.

The unaltered pre-Cambrian sedimentary rocks of the Grand Canyon region were first recognized by Powell[1] and were afterward more carefully studied by Walcott[2] at the eastern end of the Kaibab division of the canyon. They are described by Walcott as a series of sedimentary rocks 12,000 feet in thickness, comprising limestones, shales, sandstones, and interbedded flows of lava, separated both from the underlying Vishnu schist and from the overlying Cambrian sediments by profound unconformities, and exposed over a considerable area in the greater depths of the Grand Canyon and in the intercanyon valleys of the north side. To this series of sedimentary rocks Powell[3] gave the name Grand Canyon group, which was modified by Walcott to Grand Canyon series.

A slight unconformity of erosion was found in the middle of the series. The stata lying below this minor unconformity were called by Walcott the Unkar terrane, the name being derived from Unkar Valley, in which the strata are typically exposed. The rocks above the minor unconformity were called by him the Chuar terrane from typical exposures in Chuar Valley. These two valleys are parallel intercanyon valleys of the north side of the Colorado in the area described by Walcott. According to the Survey classification the Unkar and Chuar are designated as groups.

DISTRIBUTION IN THE GRAND CANYON.

At six localities in the Grand Canyon between the mouth of the Little Colorado, in the eastern end of the Kaibab division, and the mouth of Tapeats Creek, some 80 miles below, in the eastern part of

[1] Powell, J. W., Exploration of the Colorado River of the West, p. 212 and fig. 79, Washington, 1875.

[2] Walcott, C. D., Pre-Cambrian igneous rocks of the Unkar terrane, Grand Canyon of the Colorado, Arizona, with notes on the petrographic character of the lavas by J. P. Iddings: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 497–519, 520–524, 1894.

[3] Powell, J. W., Geology of the eastern portion of the Uinta Mountains: U. S. Geol. and Geog. Survey Terr., p. 70, 1876.

the Kanab division, the strata of the Grand Canyon series are exposed between the crystalline schists of the Archean and the basal sandstone of the Cambrian. Five of the localities are within the Kaibab division; the sixth is within the Kanab.

The first of these localities is the classic area below the mouth of the Little Colorado, described by Walcott. This is the largest areal exposure of these rocks in the Grand Canyon, and includes both the Unkar and Chuar groups. It extends northwestward across the canyon of Vishnu Creek and into the canyon next west of it.

The second locality lies 5 miles west of the first, at the head of the inner gorge of Clear Creek, on the north side of Colorado River, within the depths of Ottoman Amphitheater. The exposure is limited to less than a square mile. It comprises a small portion of the basal part of the Unkar group and is structurally a unit with the first locality.

The third locality lies along the north side of Colorado River at the mouth of Bright Angel Creek (Pl. X, *B*), opposite the railroad terminus and hotels of the Grand Canyon Railway, Sante Fe System. About 1,000 feet of the basal portion of the Unkar group is there represented and the areal extent of the exposure is about 3 square miles. This locality has already been described chiefly by Ransome.[1] It lies about 10 miles west of the type locality and extends southeastward across Colorado River into the canyon of Cremation Creek, along the line of a flexure in the Paleozoic strata.

The fourth locality comprises a small exposure of basal Unkar strata in the depths of Hindu Amphitheater, on the north side of the Colorado about 3 miles up Crystal Creek from its mouth, some 20 miles west of the type locality. The exposure covers about 1 square mile and has not yet been described.

The fifth locality, to be described in the present report, lies near the mouth of Shinumo Creek, about 30 miles west of the type locality. The exposures cover between 10 and 12 square miles and include rocks representing nearly the entire Unkar group.

The sixth locality is in Lower Granite Gorge just above the mouth of Tapeats Creek, in the Kanab division of the canyon. It lies 42 miles northwest of the type locality and 12 miles directly northwest of the Shinumo area. It extends about 3 miles along the river and includes about half of the total thickness of the Unkar group. This locality has not yet been described.

Dutton[2] figures "rocks of Lower Silurian and Archean unconformable" in the bed of the river beneath the "basal Carboniferous," in the western part of the Kanab division, in a section across the Grand Canyon at the foot of Toroweap Valley. As Dutton means by

[1] Ransome, F. L., Pre-Cambrian sediments and faults in the Grand Canyon of the Colorado: Science, vol. 27, No. 695, 1908.

[2] Dutton, C. E., Tertiary history of the Grand Canyon district: U. S. Geol. Survey Mon. 2, p. 88, 1882.

A. BASS LIMESTONE IN HOTAUTA CANYON.

B. STRATA OF UNKAR GROUP NEAR MOUTH OF BRIGHT ANGEL CREEK, BRIGHT ANGEL QUADRANGLE.

V, Vishnu schist; *H*, Hakatai shale; *Sh*, Shinumo quartzite; *T*, Tapeats sandstone; *B*, Bright Angel shale; *R*, Redwall limestone; *Ss*, sandstone of Supai formation; *C*, Coconino sandstone. Photograph by N. W. Carkhuff.

VIEW NORTHWARD ACROSS THE GRAND CANYON FROM THE END OF GRAND SCENIC DIVIDE.

SC, Shinumo Creek; *V*, Vishnu schist; *B*, Bass limestone; *H*, Hakatai shale; *Sh*, Shinumo quartzite; *D*, Dox sandstone; *d*, Diabase intrusive; *T*, Tapeats sandstone; *BA*, Bright Angel shale; ... *R*, Redwall limestone; *Ss*, sandstone of Supai formation; *Ssh*, shale of Supai formation; *C*, Coconino sandstone; *K*, Kaibab limestone; *WK*, West Kaibab fault.

"basal Carboniferous" what is now known as the basal sandstone of the Tonto group, of Cambrian age, it is possible that the "Lower Silurian" rocks in that locality are the Grand Canyon series. In the Shivwits division, according to Powell,[1] these rocks occur at least in one place.

STRUCTURE AND DISTRIBUTION IN THE SHINUMO QUADRANGLE.

Practically all the exposures in the quadrangle belong to the mass about the mouth of Shinumo Creek. (See Pls. IV, *B*, p. 18, and XI.) The rocks of the Grand Canyon series here lie in a wedge-shaped body, the apex of which is the intersection of the unconformities by erosion that separate them from the Archean below and from the Paleozoic above. The apex of the wedge lies near Colorado River, parallel to its northwestward course. The mass as a whole constitutes a great tilted block, which in turn consists of a great number of smaller faulted and tilted blocks pitching at successively greater angles to the northeast, away from the apex of the wedge. In the Muav-Flint Canyon, about 3 miles northeast of the apex of the wedge, the whole mass is dropped by a profound fault, which brings up the underlying Archean rocks from a great depth on the northeast side of the fault plane and produces a structure that strikingly resembles that of areas of similarly faulted Triassic blocks in the Connecticut Valley. The strike of the strata of the wedge is N. 40° W.; the dip varies from place to place. The strata of the fault blocks near the apex of the wedge generally dip 10°–15° NE.; those near the center of the wedge dip on an average about 25° NW.; but those near the great limiting fault on the northwest are completely overturned by the "drag" along the fault plane. This pre-Cambrian structure is truncated by the unconformity at the base of the Tonto group. (For structure, see Pl. I, sections, in pocket.)

The great pre-Cambrian fault that limits the wedge on the northeast is the West Kaibab fault, which displays in a most spectacular manner a phenomenon analogous to that on the line of the East Kaibab monocline, described by Walcott.[2] On the line of this ancient fault in the Shinumo quadrangle two later displacements took place after the deposition of the Paleozoic strata of the canyon wall and probably later strata. The first of these is a monoclinal flexure which reverses the throw of the pre-Cambrian fault; the second is a still more recent fault superposed upon the line of the monoclinal flexure. (Pl. I, sections, in pocket.)

On the north side of the Colorado the strata of the Grand Canyon series are exposed continuously along their strike for about 7 miles in the wall of Granite Gorge (Pl. XI), the exposures running back several

[1] Powell, J. W., op. cit., p. 62.
[2] Walcott, C. D., Study of a line of displacement in the Grand Canyon of the Colorado in northern Arizona: Geol. Soc. America Bull., vol. 1, p. 49, 1890.

miles from the river in the larger side canyons, which are cut beneath the base of the Paleozoic. These side canyons, named from east to west, are Hotauta, Shinumo, Burro, and Hakatai canyons. They are trenched directly across the strike of the strata and reveal them in cross section. The higher formations of the wedge are exposed for about 3 miles along the strike in that part of the interior gorge of the Muav-Flint canyon which lies southwest of the West Kaibab fault.

On the south side of the Colorado the exposures are confined to the basal formations and are small, for the wedge thins out in that direction. The rocks are exposed along the strike in the wall of Granite Gorge between the small canyon east of Serpentine Canyon and the mouth of Copper Canyon, a distance of 3 miles. The only long exposure across the strike is in Bass Canyon (Pl. XVI, *B*, p. 78).

The gorge of the Colorado has everywhere been trenched deep enough to expose the Archean rocks along the river beneath the Grand Canyon series (Pl. III, *A* and *B*, p. 16), for the stream flows close to the apex of the wedge.

The hard quartzite strata of the wedge resisted the erosion that preceded the deposition of the Cambrian sandstone and stood as a long, narrow residual hill or "monadnock" in the pre-Tonto plain (Pl. XVIII, p. 86). When the Tonto sea came in over the plain the monadnock formed a long rocky inland extending for an unknown distance from northwest to southeast parallel to the strike of the Algonkian strata. In many places the rocks of this island-monadnock project well above the basal sandstone of the Tonto group and are exposed in narrow outcrops above the Tonto platform, forming isolated outliers of the main mass of Algonkian strata. The largest of these outliers is in Monadnock Amphitheater, 2 miles southeast of Hotauta Canyon.

The strata of the Grand Canyon series that are exposed in Lower Granite Gorge are structurally a part of the Shinumo wedge. They represent strata of the wedge that are prolonged northwestward along the strike and reappear beyond Powell Plateau. These exposures lie just beyond the northern boundary of the Shinumo quadrangle, beginning about 2 miles down Colorado River from the north of Specter Chasm. They include about 4,000 feet of the Unkar group, which strike northwest-southeast and dip about 15° NE.

UNKAR GROUP.

CHARACTER AND SUBDIVISIONS.

The greater part of the Unkar group of the Grand Canyon series, of Algonkian age, is represented in the Shinumo quadrangle. The upper or Chuar group is not represented. Although these pre-Cambrian sediments show no more evidence of alteration or metamorphism, apart from local igneous contact phenomena, than the

overlying Paleozoic beds, they are destitute of fossils or of other evidence of life. In the absence of fossils the rocks of the group may be divided into formations by their lithology, according to which the portion of the Unkar group in the Shinumo quadrangle is divisible into five formations, which appear in conformable stratigraphic succession. The importance of this division should not be greatly emphasized, its chief value lying in the fact that it furnishes a means of comparing the lithologic succession of the Unkar group in this area with that in the type locality described by Walcott, 30 miles to the east, as well as a means of distinguishing in a broad way the main changes in the physical conditions under which these sediments were laid down.

At the base, resting upon the profoundly eroded and base-leveled surface of the metamorphic rocks of the Vishnu schist, is a thin conglomerate. Upon the conglomerate lies a series of limestones and calcareous shales. These grade upward into argillaceous and arenaceous shales which are locally intruded by a thick sill of diabase and are overlain in turn by great thicknesses of sandstone and quartzite. The uppermost exposed formation of the group in the quadrangle is a thick series of micaceous shaly sandstones.

The following section shows the geologic plan of the group and the formations into which it has been subdivided:

Section showing relations and subdivisions of Unkar group.

Tonto group.
Unconformity.
Unkar group:[1]

	Feet.
Dox sandstone (micaceous shaly sandstone)	2, 297
Shinumo quartzite (sandstone and quartzite)	1, 564
Hakatai shale (argillaceous and arenaceous shale)	580
Bass limestone (calcareous shale and limestone)	335
Hotauta conglomerate (basal conglomerate)	6
	4, 782

Unconformity.
Vishnu schist.

These strata lie in a wedge-shaped mass that is inset in the Vishnu schist (see Pl. I, sections)—a wedge composed of a great number of small tilted fault blocks, the relations showing that nowhere in the Shinumo area can the thickness of these rocks be measured in one unbroken section. As the lithologic characters of the strata are constant and the beds easily recognized, however, and as the throw of the faults that bound the tilted blocks seldom exceeds 100 feet, a section showing the unbroken sequence can be easily obtained.

Detailed sections were made from the base of the Unkar upward through each fault block until its limit was reached, and the highest

[1] The diabase that was included by W[illegible] is now known to be intrusive is, in accordance with mode[illegible]

bed measured was then located in the next block to the northeast and the measurement resumed at that point. All sections except those in the highest formation of the group were measured with a tape along the nearly vertical walls of the canyons of the Shinumo and other washes that cut across the strike of the strata. The strong drag of the great fault on the northeast has flexed and contorted the shaly strata of the Dox sandstone in such a manner that accurate measurement with the tape alone was impossible. Their thickness was computed trigonometrically, by using the combined data afforded by the tape, the topographic map, and the observed strikes and dips.

The section here given was made in two places. The greater part of it was measured in a traverse up Shinumo Canyon. This part of the section includes all the strata above the diabase sill, which is intruded midway in the Hakatai shale in that locality. A complete section of the group could have been made in a traverse of the course of Shinumo Creek from the basal unconformity at the mouth of the creek to the great fault 3 miles above, although four faults cross the creek between its mouth and the place where the diabase sill dips beneath the bed of the stream, but a place was found in Hotauta Canyon where all the strata between the basal unconformity and the diabase sill lie in a continuous unfaulted section, in a fault block that is tilted about 10° NE., so the section of the basal members of the group was measured in this locality.

HOTAUTA CONGLOMERATE.

Base of the formation.—The surface of erosion represented by the unconformity upon which the Hotauta conglomerate rests is an almost perfect plane, for nowhere in the 7 linear miles exposed in the Shinumo quadrangle is there a difference in relief exceeding 20 feet. The depth of weathering below this surface appears to be slight, in spite of the enormous amount of rock that has been removed, and the weathering appears to be the result of physical disintegration rather than of chemical decomposition.

Name and character.—The name of the formation is that of the canyon in which the lower part of the geologic section was measured.

The Hotauta conglomerate is an arkose conglomerate which varies in thickness from 1 to 6 feet in the Shinumo quadrangle. It is composed of angular or subangular fragments of the rocks of the underlying Vishnu schist, cemented by a matrix of red arkose mud, which generally contains small fragments of pink feldspar and sporadically small rounded grains of quartz.

This conglomerate varies greatly in hardness, from place to place, ranging from a hard, dense, siliceous rock, which fractures across

matrix and inclosed rock fragments alike, to an easily disintegrated rock in which the matrix crumbles away from the inclosed fragments. The degree of hardness, however, does not depend on original cementation, but on local metamorphic effects produced by the diabase sill that is intruded in the overlying rocks, the degree of induration depending on the depth of the conglomerate below the contact of the sill.

The matrix everywhere is generally of the same composition, but the character of the inclosed fragments depends on the character of the underlying Vishnu schist. The rock that underlies the conglomerate in Hotauta Canyon is the quartz diorite of the batholith already described. The diorite for 3 feet below the conglomerate is divided into roughly angular blocks by joints, which are filled with the red arkose material of the matrix. Above the diorite lies a layer of the conglomerate a foot thick, composed of weathered fragments of diorite cemented with the red arkose. Above this lies a layer, 6 inches thick, of small rounded quartz pebbles and fragments of chert like that in the overlying limestones. The whole is cemented with the red mud. Although the contact of the diorite with the mica schists in the underlying Vishnu formation is not 200 yards distant, no fragments of the mica schist were observed in the conglomerate.

In Hakatai Canyon, 4 miles west of Hotauta Canyon, the underlying rocks are mica schists and veins of quartz and pegmatite. Here the Vishnu schist is scarcely weathered at all below the unconformity. The overlying conglomerate is 6 feet thick and consists of angular fragments of the underlying mica schists, fragments of pegmatitic feldspar and vein quartz, and the arkose cement described above. The rock here is very hard, and when fractured breaks across the grains like a dense quartzite. This hardness is an effect of the intrusion of the diabase sill, the lower contact of which in Hakatai Canyon, lies only 150 feet above the basal conglomerate, whereas in Hotauta Canyon it lies 550 feet above.

Summary.—The Hotauta conglomerate is characterized by two important features—an arkose nature and a lack of sorting and transportation of its component fragments.

BASS LIMESTONE.

Name and subdivisions.—The name of the Bass limestone is derived from Bass Canyon, where the strata are typically exposed. (See Pl. X, *A*.) The following section was measured on the west side of Hotauta Canyon. The typographic arrangement shows the natural order of the beds, A representing the top bed of the section and 1 the top member of each bed.

Section of Bass limestone in Hotauta Canyon.

	Ft.	In.
A. Blue slate and white limestone	108	2
B. White limestone	105	2
C. Argillaceous and calcareous red shale and limestone	85	5
D. Basal white limestone	6	0
	304	9

Order, character, and thickness of subdivisions of the Bass limestone.

	Ft.	In.
A. Blue slate and white limestone:		
1. Layers of dense white crystalline limestone separated by bands of pale-green talcose material	2	0
2. Dense red and black banded jasper, weathering green between the layers and forming a cliff. The layers contain shrinkage cracks and ripple marks	11	4
3. Layers of dense white crystalline limestone separated by thin bands of pale-green talcose material	10	0
4. Pinkish-green fissile siliceous slate of a jaspery appearance, forming a cliff	5	0
5. Dense, lumpy white crystalline limestone	2	0
6. Fissile blue slate	7	0
7. Thin-bedded platy white limestone	4	6
8. Calcareous blue slate, forming a cliff	3	0
9. Very thin lamellar fissile blue slate	3	0
10. Thin-bedded platy white limestone	2	6
11. Dense blue crystalline limestone, forming small cliff	2	3
12. Gnarly layers of fine lamellar blue calcareous slate with a very coarse concretionary structure and irregular nodules of chert in the middle part of the bed	33	0
13. Thin-lamellar spotted blue slate	6	6
14. Same as 16, forming a small cliff		8
15. Same as 17	2	2
16. Dense purple crystalline limestone, forming a small cliff		7
17. Thin-bedded purple crystalline limestone	1	2
18. Fissile blue slates with fine partings	7	0
19. Hard blue slate, forming small cliff	1	0
20. Soft purple shale	3	6
	108	2
B. White limestone:		
1. Very hard, dense layer of flint, forming small cliff		5
2. Gnarled and nodular white cherty limestone	7	0
3. Thin-bedded crystalline white limestone	5	6
4. Thick-bedded crystalline white limestone of the same character as 8, forming a strong cliff	3	6
5. Red shale below and purple shale above, separated by a thin layer of chert	5	0
6. Undulatory-banded cherty limestone, becoming crystalline above	10	0
7. Same in thinner beds	6	6
8. Thick-bedded layers of pure, homogeneous white marble, forming the strongest cliff in the second formation of the Unkar group	6	8

	Ft.	In.
B. White limestone—Continued.		
9. Layers of undulatory-banded nodular chert in a matrix of earthy white limestone	3	10
10. Purple shale	3	3
11. Dense crystalline blue limestone		4
12. Homogeneous thin-bedded white limestone, crumbling to a white powder and weathering into plates like a shale	15	0
13. Dense blue crystalline limestone, forming a small cliff	3	0
14. Soft purple shale	1	10
15. Thin-bedded crystalline white limestone	3	10
16. Soft purple shale	1	0
17. Thin-bedded white limestone crumbling to white powder or weathering into thin plates like a shale	2	0
18. Layer of gnarled and twisted chert nodules in a matrix of white talc whose surface is covered with dendritic markings	2	0
19. Soft purple shale		5
20. Layers of undulatory-banded bluish chert	1	10
21. Purple shale	(?)	
22. Lumpy and gnarly white limestone carrying chert in large, irregular nodules. Crumbles to a white powder	2	6
23. White limestone carrying a large amount of chert in undulatory and gnarled bands	2	4
24. Homogeneous thin-bedded white crystalline limestone containing occasional thin bands of chert and nodules resembling Cryptozoon	8	6
25. Dense homogeneous white crystalline limestone, forming a cliff. Upper part is thin bedded	3	8
26. Nodular white cherty limestone. The chert occurs in irregular-shaped nodules. The upper part of the stratum has a paper-thin bedding, giving it the aspect of a calcareous shale. The limestone weathers to a white powder. Bears dendritic markings	2	0
27. Thin-bedded white cherty limestone, carrying the chert in parallel bands and containing three paper-thin layers of purple shale. Weathers to a white powder. Bears dendritic markings	2	0
	105	2
C. Argillaceous and calcareous red shale and limestone:		
1. Blue calcareous shale with an onion-like concretionary structure on a large scale	5	0
2. Dense purple calcareous shale, carrying bands of pink calcite and forming a cliff. Contains occasional thin bands of chert	9	6
3. Alternating layers of buff and red shale	13	6
4. Compact red shale, forming a cliff	8	0
5. Cherty white limestone		4
6. Red shale	4	4
7. Pink limestone	1	0
8. Blue limestone		2
9. Red shale	1	0
10. Blue limestone		3

C. Argillaceous and calcareous red shale and limestone—Con.	Ft.	in.
11. Red shale	11	0
12. Red crystalline limestone	1	0
13. Red shale	1	0
14. Red crystalline limestone	1	0
15. Calcareous red shale with three thin bands of purple limestone	9	10
16. Purple limestone		6
17. Red shale	3	10
18. Blue limestone		4
19. Red shale	1	5
20. Blue limestone, white for 1 inch at the base and showing dendritic markings		5
21. Alternating layers of buff and chocolate-red shale with a splintery habit of weathering and a roughly concretionary structure. Like all the succeeding shales and sandstones of the Unkar group, they are mottled with light spots, generally circular or elliptical in form and of all sizes	5	6
22. Purple crystalline limestone	1	0
23. Purple shale with occasional bands of purple calcite	4	0
24. Purple cherty limestone	1	0
25. Soft purple shale		6
	85	5
D. Basal white limestone:		
1. White cherty limestone carrying the chert in thin parallel bands, which are etched out by the weather on the cross sections. The surface of each chert layer shows polygonal cracks suggestive of sun cracks in shale. This structure belongs to each separate chert layer and is not a columnar structure. The weathered surfaces of these chert layers are dotted with small cubic depressions which were apparently formed by the leaching out of some mineral of cubic form	4	6
2. White nodular cherty limestone. The chert occurs in nodules having a roughly concentric structure somewhat suggestive of the structure of Cryptozoon	1	6
	6	0

Specimens of these limestones when examined in the laboratory proved to be more or less magnesian, and all those of division B were found to be dolomites.

Thin sections were cut from specimens taken from 20 separate beds in division B. Eighteen of these slides were cut from the limestone strata and two from the red shales. The sections of the limestones were cut both from the chert bands and nodules and from the limestone itself, for the purpose of ascertaining the exact mineralogical character of these rocks and in the hope that they might reveal traces of a structure that could be referred to something organic. The microscope revealed no minerals other than calcite and quartz in any of the slides. The silica of the chert bands and nodules

appeared in the form of interlocking grains of quartz. None of these grains were rounded and there was no evidence that the quartz grains represented an inwashed sand. No trace of organic structure was revealed either in the chert or in the limestone. The purer limestones were found to consist of calcite (or dolomite) alone, the crystalline forms having the typical structure of marble. The impure varieties were seen to consist of mixtures of quartz and calcite in all proportions, the greater part of the limestone being of this impure character. The shales were found to consist of a fine, impalpable ferruginous or calcareous mud, containing here and there a minute grain of quartz.

Summary.—The section of the Bass limestone shows several interesting features. Ripple marks and sun cracks appear for the first time in the shales in stratum 2 of division A, just below the limestone stratum at the summit of the formation. An increase in the intensity of local metamorphism in the section from the base upward was also noted, the rocks becoming harder and changing in color with increasing proximity to the lower contact of the diabase sill, which is intruded in the overlying Hakatai shale. Nearly all the shales of division C are red, but from the summit of this division upward they are purple and blue. The shales below division A are soft and crumbly; those in this division, however, have become dark-blue slates, and those in the upper part of the section have become extremely hard, siliceous jaspers.

The section is broadly characterized by oft-repeated alternations of limestone and shale, and according to the dominance of one or the other type of rock the four divisions A, B, C, and D, are separated: D is entirely limestone; C is alternating limestone and shale; B is predominantly shale; A is largely slate and jasper. Thus there are four major cycles of oscillation of sediments upon which the minor cycles are superimposed.

A comparison of the above section in Hotauta Canyon with a section measured in Hakatai Canyon, 4 miles to the west, is of interest. In Hakatai Canyon the "basal white limestone" (D) has a thickness of 30 feet, contrasted with a thickness of 6 feet in Hotauta Canyon. The thickness of lower stratum of "white, nodular, cherty limestone" in Hakatai Canyon is 7 feet 9 inches, whereas in Hotauta Canyon it is only 1 foot 6 inches. The upper stratum of this section, a parallel-banded, cherty, white limestone, which is 4 feet 6 inches thick in Hotauta Canyon, is 22 feet 3 inches thick in Hakatai Canyon, and contains in the middle an intercalated layer of purple shale and near the top a thin layer of rather fine arkose conglomerate. In Hakatai Canyon the "argillaceous and calcareous red shales and limestones" of division C are 88 feet thick, but in Hotauta Canyon they are 85 feet 5 inches thick and have not the red color that characterizes

them in Hakatai Canyon, being purple and blue and much indurated. This change of color and difference in hardness are due to their closer proximity to the diabase sill in Hakatai Canyon.

The correspondence in the lithologic character and vertical succession of the beds of these two sections, 4 miles apart, is so close that the individual strata of the sections can be matched bed for bed.

The only marked contrast in thickness occurs in the basal white limestone (D).

HAKATAI SHALE.

The name of the Hakatai shale is taken from Hakatai Canyon, where the formation is typically exposed.

Section of Hakatai shale.

	Ft.	in.
A. Alternating vermilion arenaceous shale and sandstone	78	1
B. Alternating vermilion argillaceous shale and sandstone	109	4
C. Red argillaceous shale	81	0
D. Blue slate	100	0
E. Blue slate and quartzite	20	0
F. (Intrusive diabase.)		
G. Red and blue jasper	31	0
H. Sandy quartzitic jasper	52	0
I. Cliff-forming jasper	17	6
J. Blue slate with calcareous band	18	0
K. Cliff-forming jasper	73	0
	579	11

Order, character, and thickness of subdivisions of the Hakatai shale.

	Ft.	in.
A. Alternating vermilion arenaceous shale and sandstone	78	1
B. Alternating vermilion argillaceous shale and sandstone	109	4
C. Red argillaceous shale, sun cracked throughout. The rock is very soft and forms a slope together with the underlying blue slate	81	0
D. Blue slate, forming a slope	100	0
E. Blue slate and quartzite, forming a cliff	20	0
F. At this horizon is intruded a sill of diabase whose thickness varies from 650 feet on Shinumo Canyon to 950 feet or more in Hakatai Canyon. The section from A to F was measured in a traverse up the Shinumo, starting with the upper contact of the diabase sill.		
G. Red and blue jasper:		
1. Red and black banded jasper	9	0
2. Banded blue jasper with curious spots, sun cracked throughout	22	0
	31	0
H. Sandy quartzitic jasper:		
1. Fine-grained pink sandy jasper, sun cracked	11	0
2. Fine-grained pink quartzite	4	0
3. Pink quartzitic jasper	5	0

	Ft.	in.
H. Sandy quartzitic jasper—Continued.		
4. Fine-grained pink quartzite, ripple marked	1	0
5. Slaty-blue spotted jasper with sun cracks	6	0
6. Fine-grained pink quartzite	4	0
7. Slaty-blue spotted jasper	12	0
8. Fine-grained pink quartzite, ripple marked	5	0
9. Slaty-blue spotted jasper	4	0
	52	0
I. Cliff-forming jasper:		
1. Dense, hard layer of blue-black jasper mottled with red spots, having a soft, slaty layer at the base and forming with the bed below a strong overhanging cliff	3	6
2. Same as 1, without soft layer	14	0
	17	6
J. Calcareous blue slate:		
1. Slaty-blue jasper with small red spots	4	6
2. Pink crystalline limestone	1	6
3. Slaty black jasper, sun cracked throughout	12	0
	18	0
K. Cliff-forming jasper:		
1. Dense, hard layer of blue-black jasper, showing banded structure, with a soft layer at the base	12	0
2. Same as 1	14	0
3. Same general character as 2. The lower 2 feet are slaty and weather out, giving the cliff an overhang	19	0
4. Dense, hard layer of blue-black jasper, mottled with red spots and showing no banding in the mass, forming with the three layers above a strong perpendicular cliff. This is the most resistant rock in the Unkar group. Where the under surface shows beneath the overhang of the cliff, it is sun cracked on a large scale and in several generations	28	0
	73	0

The sandstone in series A is white, compact, and fine grained. It is cross-bedded and ripple marked throughout. The under surface of each sandstone layer is sun cracked where it rests upon the arenaceous shale. The shale is vermilion in color, soft, and very sandy. Sun cracks occur throughout.

The succession is as follows:

	Ft.	in.
1. Sandstone	1	0
2. Arenaceous shale	24	0
3. Sandstone	2	0
4. Arenaceous shale	11	8
5. Sandstone	9	0
6. Arenaceous shale	21	1
7. Sandstone	9	4
	78	1

The alternations in series B are remarkably regular. The sandstone is white, compact, and fine grained and is cross-bedded and ripple marked throughout. The shales of the alternating beds are very soft and weather out, leaving etched-out bands between the sandstones, which are very conspicuous in the cliff faces. On the under surface of each sandstone layer are well-preserved sun cracks. The shales are fine grained, fissile, and argillaceous.

The succession in this alternating series is as follows:

Order and thickness of beds of sandstone and shale in series B of Hakatai formation, with thickness of groups of beds representing each sandstone-shale cycle.

	Ft.	In.	Ft.	In.
1. Shale	4	0	7	0
2. Sandstone	3	0		
3. Shale	6	6	8	6
4. Sandstone	2	0		
5. Shale	2	6	6	4
6. Sandstone	3	10		
7. Shale	1	0	3	0
8. Sandstone	2	0		
9. Shale	0	6	4	0
10. Sandstone	3	6		
11. Shale	4	0	11	6
12. Sandstone	7	6		
13. Shale	3	6	9	6
14. Sandstone	6	0		
15. Shale	3	6	9	6
16. Sandstone	6	0		
17. Shale	2	6	8	6
18. Sandstone	6	0		
19. Shale	3	0	8	0
20. Sandstone	5	0		
21. Shale	10	6	17	6
22. Sandstone	7	0		
23. Shale	2	0	3	0
24. Sandstone	1	0		
25. Shale	3	0	5	0
26. Sandstone	2	0		
27. Shale	3	10	8	0
28. Sandstone	4	2		
Total	109	4	Average 7	10

Thin sections were cut from several specimens of the jaspers, but they were unsatisfactory, because of the exceedingly fine grain of the rock. The highest power of the microscope revealed nothing more than an impalpable silicified mud. A slide of the "quartzitic jasper" showed that the rock was a somewhat arkose sandstone indurated to a siliceous quartzite, composed chiefly of small rounded quartz grains about which secondary silica had been deposited, lying in a fine arkose matrix made up of small fragments of pink feldspar. A thin

section was also made from a specimen of sandstone taken from one of the layers in the "alternating argillaceous shale and sandstone" of division B. The rock proved to consist of small, well-rounded grains of quartz, cemented by silica in the form of secondary quartz. It is a pure, fine-grained sandstone.

The metamorphic effects produced by the diabase sill intruded at the horizon F are seen in the section marked "I." This metamorphic action produces induration by silicification, forming jaspers; induration by baking, forming slates; decoloration, red changing to blue and black.

In the summary of the features of the Bass limestone it was noted that the shales became successively slates and jaspers above, while their color changed from red to blue. In division I of the Hakatai formation the shales are represented entirely by jaspers and quartzites. (See Pl. XIV, *B*, p. 64.) Just below the contact, at the top of division G, the induration is very great, and the jaspers are tough and vitreous; their prevailing color is blue or black. Above the contact the overlying rocks are hard blue slates for 20 feet, succeeded by 100 feet of less indurated slate, grading up into the original red shale.

The metamorphic effects above and below the contact differ in intensity as well as in kind; above the contact the induration and decoloration characterize only about 100 feet of strata; below the contact they extend through 300 feet. Above the contact the strata have been baked and decolored only, the red shale changing to a blue slate; below the contact considerable silica has been added, transforming the red shales to blue and black jaspers; added to this are the effects of baking and decoloration.

The Hakatai formation is characterized by argillaceous shales in its lower portion, which grade upward into arenaceous shales and sandstones through the interesting series of alternations described in division B. Nearly every stratum in the formation bears marks of shallow-water origin—sun cracks, ripple marks, or cross bedding.

SHINUMO QUARTZITE.

The following section of the Shinumo quartzite was made in the canyon of Shinumo Creek (see Pls. VIII, *A*, p. 28, and XII, *B*), whence the name of the formation is derived:

Section of Shinumo quartzite in Shinumo Canyon.

	Feet.
A. Irregularly bedded sandstone:	
1. Cross-bedded green sandstone	21
2. Banded purple sandstones	20
3. "Curiously twisted and gnarled layers" of fine-grained white sandstone containing large red [illegible] and elliptical form. The upper part [illegible] more massive. The twisted and [illegible] seems to have been a [illegible]	

	Feet.
deposition and suggests that the original sand was moist and plastic and once flowed by rolling over and over in the form of a quicksand	105
(A bed of this character is described by Walcott in his section in Unkar Valley. (Walcott, Fourteenth Ann. Rept. U. S. Geol. Survey, p. 511.) It occurs at the same horizon as the bed described above and contains the same red spots.)	
B. Banded white quartzite	20
C. Compact cliff-forming white quartzite of the same character as G below, though not so massive in structure	250
D. Fine-grained purple sandstone with a white band in the middle. The white band is constant and is a conspicuous feature by which this sandstone can be distinguished at a distance of several miles. The rock is cross bedded and in some places displays a "twisted and gnarled" structure	150
E. Banded white quartzite, stained magenta on the exposures and forming a cliff	120
F. Purple-brown fine-grained sandstone containing lenses of conglomerate and thin beds of shale	353
G. Compact white quartzite of fine and uniform grain, displaying a faint cross-bedded structure. This quartzite is the most resistant rock in the formation. It is exposed everywhere in one massive perpendicular cliff face, which does not display the slightest break except where it is cut by faults. Wherever its base rests upon a shaly lens its under surface displays well-preserved mud cracks. The face of the cliff is stained magenta by the ferruginous cement that washes down from the shale lenses in the overlying sandstones	119
H. Purple-brown sandstone of fine grain containing in some places an occasional lens of fine conglomerate and a thin local bed of red or purple shale. Cross bedded throughout	406
	1,564

An examination of slides cut from several specimens of the sandstones and quartzites showed that they consist of small rounded quartz grains, few of which exceed 0.7 millimeter in diameter. This extreme fineness and roundness of the grains, as well as the cleanness of the sorting, is remarkable. The cement is generally siliceous, in places slightly ferruginous. A slide made from a specimen taken from one of the small conglomerate lenses in division H showed that the rock consisted of small rounded quartz pebbles lying in a fine arkose matrix, and disclosed also occasional large angular fragments of orthoclase and microcline.

The Shinumo quartzite (Pl. XII, *A*) is the most resistant rock in the Grand Canyon series, its beds forming the Algonkian monadnocks, which appear in all parts of the Grand Canyon. In the canyons that are cut across the strike of the strata, such as the deep canyons of the

A. SHINUMO QUARTZITE NORTH OF CABLE CROSSING.

Sh, Shinumo quartzite; *H*, Hakatai shale; *d*, Diabase intrusive.

B. QUARTZITE IN CANYON OF SHINUMO CREEK.

Shinumo Garden, irrigated from Shinumo Creek, is shown in lower right corner of view.

Shinumo, these beds stand in great plunging cliffs (Pls. VIII, *A*, p. 28, and XII, *B*).

The Shinumo quartzite includes great thicknesses of pure, fine-grained, uniform sandstone. All its beds are very resistant and form cliffs, and many of them show ripple marks and cross bedding.

DOX SANDSTONE.

The name Dox sandstone is derived from Dox Castle, underneath which a typical section is found beneath the formations of the Tonto group, which make the castle. The following section was measured on the west side of the canyon of Shinumo Creek (Pl. XIII, *B*):

Section of Dox sandstone in Shinumo Canyon.

	Feet.
A. Red and vermilion micaceous shaly sandstones, cross bedded and ripple marked, with arenaceous and argillaceous shaly partings, which display well-preserved mud cracks. The shaly partings are either green or red	1,197
B. Gray-green, pinkish-green, and brown micaceous shaly sandstones, cross bedded and ripple marked, varying in character only through gradations in color. Many arenaceous and argillaceous shaly partings occur, causing the rock to weather like a soft sandy shale. Most of the shale partings are green. Some of the sandy layers near the base show a "gnarled and twisted structure"	1,100
	2,297

The beds above the top of this section have been removed by erosion, the top of the highest bed of division A marking the plane of the pre-Tonto unconformity. The highest beds of this division lie at the upper end of the dry wash that joins the canyon of Shinumo Creek from the north just below the mouth of White Creek. The beds are dragged up against the Vishnu schist by the great pre-Cambrian fault, and the whole series is overlain by the basal (Tapeats) sandstone of the Tonto group. (See Pl. I, sections, in pocket.)

The Dox sandstone may be summarized as a series of micaceous shaly sandstones of uniform character, varying only in color and bearing marks of shallow-water origin throughout.

COMPARISON WITH TYPE SECTION IN UNKAR VALLEY.

A comparison of the above section of the Unkar group with that described by Walcott[1] in the type locality, 30 miles to the east, reveals the fact that the two sections correspond closely in thickness and in lithologic succession; only in their lower parts do they differ materially. The type section in Unkar Valley is characterized by a greater thickness of the basal conglomerate and by only a third as

[1] Walcott, C. D., Pre-Cambrian igneous [illegible] Canyon of the Colorado, Arizona: U. S. Geol. Survey Fourteenth Ann. [illegible]

much limestone in the members that correspond to the Bass limestone; the deficiency in limestone is made up by a greater thickness of arenaceous and argillaceous shales. The beds farther up in the section, in that division of Walcott's section which corresponds to the Hakatai shale, contain a greater proportion of sand. The succeeding members correspond closely in character and thickness even to the minor divisions, an example being the "gnarled and twisted layers" previously cited.

The writer had the privilege of examining Mr. Walcott's field specimens in the National Museum at Washington and was particularly impressed by their absolute lithologic identity with the series collected by himself from corresponding horizons on Shinumo Creek. The two series of specimens, those of rocks altered by local metamorphic phenomena, might have come from the same locality.

AGE AND CORRELATION OF THE GRAND CANYON SERIES.

By the usage of the United States Geological Survey the Grand Canyon series is referred to the Algonkian system. It has been tentatively correlated with the Keweenawan series of the Lake Superior region by Walcott,[1] and according to Darton [2] it may also be correlated with a series of Algonkian rocks that occur in the Fort Apache region in Arizona.

During the summer of 1909 the writer had the opportunity of studying the rocks of the San Juan Mountains in southwestern Colorado, under the direction of Mr. Whitman Cross, and was particularly impressed with the similarity of the Needle Mountains group (Algonkian) to the Grand Canyon series, both in stratigraphic position and general lithology.[3] Like the Grand Canyon series, the Needle Mountains group (consisting of the Vallecito conglomerate below and the Uncompahgre formation, composed of quartzites and slates, above) rests unconformably upon a very old metamorphic complex and is likewise separated from an overlying Cambrian sandstone by a great angular unconformity which represents a base-leveled surface of erosion and truncates the pre-Cambrian structure as completely as does the pre-Tonto unconformity in the Grand Canyon region. The basal Cambrian sandstone of the San Juan region is similar in every respect to the basal (Tapeats) sandstone of the Tonto group and should doubtless be correlated with that formation. Lithologically the Needle Mountains group resembles the Grand Canyon series in the great amount of cross-bedded quartzitic sandstone it includes, but it differs from the Grand Canyon series in containing a great thickness of coarse conglomerate in its basal part and in exhibiting

---

1 Walcott, C. D., Pre-Cambrian igneous rocks of the Unkar terrane, Grand Canyon of the Colorado: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, p. 518, 1894.

2 Darton, N. H., A reconnaissance of parts of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, 1910.

3 Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Needle Mountains folio (No. 131), 1905.

A. VIEW NEAR CABLE CROSSING, LOOKING DOWN COLORADO RIVER.

V, Vishnu schist; *B*, Bass limestone; *H*, Hakatai shale (jasper); *d*, Diabase intrusive.

B. DOX SANDSTONE IN CANYON OF SHINUMO CREEK, OVERLAIN UNCONFORMABLY BY TAPEATS SANDSTONE OF THE TONTO GROUP.

***D*, Dox sandstone;** *T*, Tapeats sandstone; *M*, Muav limestone; *R*, Redwall limestone. Photograph by N. W. Carkhuff.

A. SHINUMO CREEK.

B. BEDROCK TANK, BASS CANYON.

LOWER CONTACT OF DIABASE SILL.

H, Hakatai shale, here converted to jasper; *d*, Diabase; *T*, Tapeats sandstone.

metamorphism by pressure, whereas the Grand Canyon series is unaltered. In the opinion of the writer there is little doubt that the Needle Mountains group is the correlative of the Grand Canyon series.

INTRUSIVE DIABASE ASSOCIATED WITH THE UNKAR GROUP.

OCCURRENCE.

The diabase in the Shinumo quadrangle occurs in the form of intrusive sheets, or sills, which lie between the beds of the Unkar group.

In the uppermost part of division A of the Dox sandstone are four thin sills of diabase, the largest less than 25 feet thick, which are extremely rotten, weathering green and crumbling to small fragments. They occur between vermilion beds of sandstone and shale, and their intrusive character is shown by the fact that the vermilion beds are baked and decolorized for a few inches above and below the diabase, the vermilion color having been changed to purple. The diabase of these sills is too much weathered to permit an exact petrographic determination of its character in a thin section.

The greater part of the diabase forms a single mass, which occurs at three or more stratigraphic horizons in the sediments of the Unkar group in different parts of the quadrangle. (See Pls. XIII, *A*, XIV, *A* and *B*, and XVIII, p. 86.) In Hakatai Canyon, 3 miles west of Shinumo Creek, it lies within the Bass limestone. On the east side of Hakatai Canyon it rises out of the Bass limestone and enters the Hakatai shale, breaking clean across the edges of the intervening strata. Most of the lower and part of the upper contact of the eruptive rock are clearly displayed in the walls of this canyon. Between the exposures in Hakatai Canyon and the main exposures of the Unkar group about the mouth of Shinumo Creek the pre-Cambrian structure is hidden beneath the basal (Tapeats) sandstone of the Tonto platform. In all the region about the mouth of Shinumo Creek the diabase lies within the Hakatai shale at a horizon 400 feet above that at which it occurs in the Bass limestone in Hakatai Canyon. (See Pls. XIII, *A*, and XIV, *A* and *B*.) East of Hotauta Canyon, on the Colorado, the Unkar structure is again hidden beneath the Tonto platform, but about 3 miles up the river from Hotauta Canyon small outcrops of the basal formations of the Unkar group are again exposed in the intercanyon valleys on both sides of the river, where the lower contact of the diabase lies just at the summit of division B of the Bass limestone.

So much of the exposed portion of the sill is traversed by faults that lie parallel to the strike of the strata that it is impossible to measure it exactly. Its thickness reaches a maximum of about 1,000 feet on the west side of the Hakatai Canyon and decreases gradually eastward.

PETROGRAPHY.

Megascopic features.—Fresh specimens typical of the greater part of the mass show that the diabase is a tough, heavy, holocrystalline rock of medium to coarse grain and of gray color. The minerals visible to the unaided eye are plagioclase, olivine, augite, and an occasional grain of magnetite. Although the olivine exceeds the augite in amount, it is less conspicuous to the eye. Aside from a somewhat waxy luster of the feldspars the rock is remarkably fresh. The weathered surface has a characteristic warty appearance, imparted by the presence of lumps or balls which are more resistant than the mass of the rock and of coarser grain and different texture. These lumps and balls consist of coarse ophitic intergrowths of augite and plagioclase. The diabase weathers by mechanical disintegration to a greenish-olive sand, in which lie innumerable lumpy kernels of all sizes derived from the ophitic masses described above. The rock has no typical columnar structure, but generally displays a rough vertical jointing, such as is characteristic of granite.

Microscopic features.—The slides examined show that the typical rock consists primarily of plagioclase feldspar (near labradorite) and olivine in about equal amounts, a subordinate quantity of augite and brown biotite, and very little magnetite. The feldspar is somewhat altered, but all the other minerals are fresh. The olivine occurs characteristically in rather large rounded crystals of automorphic habit. The augite is confined chiefly to the globular masses, which weather out as lumps and kernels, and does not characterize the rock as a whole. Slides cut from these kernels show that they are composed entirely of augite and feldspar. The augite is inclosed within the feldspar, displaying fine examples of ophitic texture. Several of the magnetite crystals have rims of brown biotite. The small amount of magnetite is rather remarkable, and it seems likely on this account that the olivine is rich in magnesia. Because of the predominance of olivine and plagioclase in the greater part of the rock, the diabase is classified as an olivine diabase with a troctolitic aspect.

VARIATIONS IN CHARACTER.

All parts of the mass are subject to variations in texture and composition toward a coarser grain. These variations are of two types. The first type occurs in the ophitic intergrowths of augite and plagioclase of the lumps and balls described above, and is a segregation phenomenon characterizing the mass as a whole. In some places this texture becomes very coarse, the separate crystals of augite or plagioclase being an inch in length. The second type occurs in typical pegmatite dikes, which cut the diabase in many places and vary in width from a few inches to several feet. The minerals are

plagioclase and augite and the texture is usually, but not invariably, ophitic. In some of these dikes crystals of plagioclase exceeding 3 inches in length were observed.

The contact facies of the diabase are in places fine grained or glassy, but for only a few inches from the contact. The slides typical of this zone reveal a hyalopilitic arrangement of glass, with skeleton crystals of magnetite between much altered crystals of feldspar.

For about half a mile east and half a mile west of the canyon of Shinumo Creek a pink holocrystalline rock of medium grain occurs in the upper part of the diabase sill along the upper contact. Its contact with the overlying blue slates is sharp and well defined, and it appears to grade downward into the normal diabase, no definite line of contact having been anywhere observed.

A slide cut from a specimen taken from the middle of a pink mass of the sill showed that it is a granular rock of medium texture, consisting of rather fresh crystals of orthoclase, with subordinate quartz and a somewhat altered ferromagnesian mineral, which appeared to have been originally a hornblende. Some of the quartz displayed a micrographic arrangement within the feldspar. The rock is a typical hornblende syenite and is apparently an interesting example of differentiation in place within the diabase sill.

In Hakatai Canyon both the lower and upper eruptive contacts of the diabase are ragged and considerably injected. Many small dikes penetrate the country rock from the main mass. They are glassy in texture and greatly altered.

Ransome [1] describes a diabase of post-Carboniferous age occurring in thick sills in the pre-Carboniferous sedimentary rocks in the Globe Copper district in Arizona. This diabase closely resembles the Algonkian diabase described above both in mineralogic character and in the presence of the ophitic balls of plagioclase and augite. The analogy is made the more striking by the fact that several small masses of pink hornblende syenite are described as occurring within the diabase sills of the Globe district, possibly as segregations within the diabasic magma.

CONTACT METAMORPHISM.

As the diabase sill occupies different horizons in the Unkar group in the canyon of Shinumo Creek and in Hakatai Canyon, and as the strata between which the sill is intruded in Shinumo Canyon lie in undisturbed sedimentary contact in Hakatai Canyon, and vice versa, the effects of the intrusion on the invaded strata can be easily noted.

The contact effect upon the shales that lie above and below the diabase along Shinumo Creek has already been described in the

[1] Ransome, F. L., Geology of the Globe Copper district, Arizona: U. S. Geol. Survey Prof. Paper 12, p. 80 et seq., 1903.

detailed section of the Unkar group, where the shales were shown to be altered to jaspers by baking and silicification (Pl. XIV, *B*). The intensity of metamorphic action was much greater below the sill than above, extending through 300 feet of strata below the lower contact and through only 100 feet above the upper contact. In Hakatai Canyon these rocks lie in undisturbed sedimentary contact and are there unaltered red shales.

The contact effect on the limestones can be studied in Hakatai Canyon, where the diabase sill lies intruded within them. Immediately below the lower contact of the diabase, which is sharp and well defined, is a thin layer of green serpentine. Below lie layers of pure crystalline limestone (dolomite) alternating with similar layers containing bands and nodules of serpentine. Within one of the layers containing the bands and nodules of serpentine are cross-fiber veins of golden-yellow chrysotile asbestos, which are parallel in general trend to the bedding of the limestone. These limestones are the layers at the base of division B of the Bass limestone. They overlie the red shales of division C, which are here baked to blue slates.

The following section, including a part of the Bass limestone beneath the lower contact of the diabase near the tunnel of the Asbestos mine in Hakatai Canyon, shows effect of local metamorphism in the strata. The numbers of the beds correspond (so far as the beds can be identified) to the numbers used in the detailed section of the Unkar group (pp. 40–53). The printed section represents the natural order, B, 24, 25, being at the top.

Section of part of the Bass limestone beneath diabase sill at the Asbestos mine in Hakatai Canyon.

		Ft.	In.
Diabase sill		1,000±	
B, 24, 25.	Layer of green serpentine	2	
	Pure white crystalline limestone	1	6
	White crystalline limestone, with bands and nodules of serpentine	2	
	Serpentinous nodular and banded layer carrying veins of asbestos	1	
	Banded crystalline limestone, with bands and nodules of serpentine	10	
B, 26, 27.	Nodular cherty limestone	4	
C, 1.	Soft blue slate	3	
C, 2.	Dense purple calcareous slate	9	

ASBESTOS.

Occurrence.—The limestones above the upper contact of the diabase contain several alternating layers of green serpentine and narrow veins of asbestos, which occur at several horizons near the contact.

The geologic occurrence of the asbestos is fully described by Diller.[1] A microscopic study was made of 25 thin sections cut from the limestones, the bands and nodules of serpentine, and the veins of asbestos. Aside from the serpentine and asbestos no other minerals were revealed in the limestones than the dolomitic calcite and interlocking grains of quartz in the slides cut from the limestones of the same horizon in the section in Hotauta Canyon, where the same strata lie in undisturbed sedimentary contact. The limestones have the texture of marble. The serpentine of the bands and nodules shows no trace of alteration in structure due to derivation from pyroxene, hornblende, or olivine. The slides cut across the veins of asbestos showed that they are later than the serpentine in which they are generally inclosed. A great number of microscopic veins of asbestos were revealed in some of the slides where their presence was unsuspected. Some of these veins cut across both the sepentine and the limestone in the same slide.

The asbestos in the larger veins is of high grade and is said by Diller to be the best yet found in the United States.[2] Locally its cross fiber is 4 inches in length and is of great tensile strength. The larger veins, so far as known, are confined to the limestones that lie beneath the diabase sill, the veins above the sill, though more widely distributed through the limestones, being generally smaller. The veins below the sill are not absolutely constant in stratigraphic position; they may lie anywhere from 3 to 15 feet below the contact. The width of these veins varies greatly from place to place, so that a vein that is 3 inches wide in one locality may be represented by a zone of innumerable small veins in another, but the actual continuity of the zone that carries the asbestos is rarely broken.

Origin.—The limestones contain serpentine and asbestos only where the strata are invaded by the diabase sill; the shales that are invaded by the diabase do not contain these minerals, which in no place in the area occur within the diabase itself. They are therefore a product of the contact metamorphism of the limestones by the diabase, and, as Diller suggests,[3] the serpentine that incloses the veins of asbestos is probably derived from some mineral in the limestones and not from the diabase. The limestones themselves are magnesian and contain bands and nodules of chert. In another part of the area the shales in contact with the diabase were converted to jaspers, the change indicating that the fumarolic action accompanying the injection of the diabasic magma was characterized by aqueous and probably siliceous emanations and was fairly intense.

[1] Diller, J. S., U. S. Geol. Survey Mineral Resources, 1907, pt. 2, pp. 720-721, 1908; idem, 1908, pt. 2, p. 705, 1909.

[2] Diller, J. S., U. S. Geol. Survey Mineral Resources, 1908, pt. 2, p. 705, 1909.

[3] Diller, J. S., loc. cit.

The fumarolic action on the magnesian limestones may have converted their more siliceous portions into serpentine. The occurrence of the asbestos in veins that cut across both the nodules of serpentine and the limestones shows that the cross-fiber asbestos was formed somewhat later in the sequence of events attending the fumarolic action.

AGE OF THE DIABASE.

The sills of diabase are displaced by the faults of the wedge in the same manner as the inclosing strata, the invasions having evidently occurred before the faulting. (See Pl. I, sections, in pocket.) The diabase of the Shinumo quadrangle is closely related in chemical and mineral composition to the basalt of the lava flows described by Iddings,[1] which are interbedded with the sediments of the upper part of the Unkar group in the type section in Unkar Valley. As the diabase lies at a much lower horizon than the lava flows, it is probably an intrusive rock of the same cycle of igneous activity, the sills and flows being probably contemporaneous.

PALEOZOIC ROCKS.

RESULTS OF PREVIOUS WORK IN THE REGION.

In a large and general way the distribution and broader character of the Paleozoic rocks of the Grand Canyon are familiar to every geologist through the writings of Newberry, Ives, Powell, Gilbert, Dutton, and Walcott.[2] A thorough analysis of their topographic and scenic expression in the canyon has been made by Davis.[1]

The details of the stratigraphy, however, are not yet known. Sections have been made at several widely separated places in the canyon wall—in the eastern part of the Kaibab division, by Walcott and by Frech; at Kanab Canyon, in the Kanab division, by Walcott; and at Diamond Creek and at the Grand Wash, in the Shivwits division, by Gilbert.[2] A recent report by Darton [2] gives a compilation of these sections and some additional data collected by himself at many points in the region. In all these sections and in this report certain groups of strata, particularly the Tonto, are given in detail, but no single section includes all the beds of all the groups in the Paleozoic rocks at any one place. A close and accurate comparison and correlation of the thickness and character of the Paleozoic formations from place to place in the Grand Canyon must therefore depend on the results of future detailed work at many points.

[1] Walcott, C. D., Pre-Cambrian igneous rocks of the Unkar terrane, Grand Canyon of the Colorado, Arizona, with notes on the petrographic character of the lavas, by J. P. Iddings: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 520 et seq., 1894.

[2] See Bibliography, pp. 13-15.

GENERAL SUCCESSION OF THE PALEOZOIC ROCKS.

At the base of the Paleozoic is the Tonto group, of Cambrian age. This group is divisible into three formations. At the base, resting in some places upon Archean and in other places upon Algonkian rocks, is the Tapeats sandstone. Overlying the sandstone is the Bright Angel shale, containing Middle Cambrian fossils. The highest formation of the group is the Muav limestone. No representatives of the Ordovician, Silurian, or Devonian were discriminated in the area studied, the Muav limestone being succeeded without apparent stratigraphic break by the Redwall limestone, of Carboniferous age. The Redwall limestone is overlain by the Aubrey group, which is also of Carboniferous age, and is divisible into three formations. At the base of the Aubrey group is the Supai formation composed of sandstone and shale, which is in turn overlain by the Coconino sandstone. The highest formation of the group, and likewise of the Paleozoic in the quadrangle, is the Kaibab limestone, containing a Pennsylvanian fauna. (See Pl. XVIII, p. 86.)

CAMBRIAN SYSTEM.

TONTO GROUP.

TAPEATS SANDSTONE.

The Tapeats sandstone rests upon an eroded surface which bevels the upturned and truncated edges of the Vishnu schist and Grand Canyon series. This unconformity is in plain view in the walls of the Granite Gorge throughout the entire Kaibab division of the canyon and is probably the clearest and most spectacular illustration of such a geologic feature in the world. Except in localities where remnants of Algonkian strata are preserved, the Tapeats sandstone in this division everywhere rests upon Archean rocks, yet we know from the record in the Vishnu quadrangle that at least 12,000 feet of Algonkian strata was deposited horizontally upon the Archean and that these Algonkian rocks were profoundly tilted and faulted before they were eroded away. So vast was the erosion that all but a few remnants of Algonkian strata were removed and the Archean rocks make the greater part of the floor on which the Tapeats sandstone was laid down. This floor, like that upon which the basal strata of the Unkar group were deposited, represents a surface base-leveled by erosion. This surface was not nearly so even as that represented by the more ancient pre-Unkar unconformity, yet it formed a comparatively level plain. Here and there a knob of more resistant Archean rock projects into the Tapeats sandstone, [illegible] Monadnock amphitheater the rocks of the Unkar [illegible] feet

above the base of the sandstone, almost cutting out the overlying Bright Angel shale, but the relief of even these exceptional projections is small in comparison with the horizontal extent of the floor.

The name Tapeats sandstone is derived from Tapeats Creek, below the mouth of which, just north of the Shinumo quadrangle, the bed of the Colorado River lies within this formation.

The Tapeats sandstone shows little variation in lithologic character in the Kaibab division. The following is a typical section in the Shinumo quadrangle (reading from the top downward, A being the top bed, underlain by B and C):

Section of Tapeats sandstone.

	Feet.
A. White cross-bedded sandstone containing "Scolithus"	35
B. Shaly brown or greenish sandstone	50
C. Brown slabby sandstone or pebbly grit, composed chiefly of particles of quartz and characterized by cross bedding. The basal portion generally includes beds of coarser grit, or conglomerate, made up of the harder fragments of the underlying rocks. Most of the pebbles are rounded. The member contains here and there thin lenses of shale. The sandstone is commonly indurated to quartzite and the entire member is very resistant to erosion and makes a conspicuous brown cliff along the rim of the Granite Gorge. The thickness depends on the relief of the underlying surface; where greatest it is	200
	285

No fossils were found in the formation.

Within the Tapeats sandstone is a record of marine planation that in these vertical sections, which include no soil, is preserved with a clearness that is almost beyond belief. The long southwestern face of the Unkar island monadnock was undercut by the waves of the sea in which the sandstone was deposited, and a cross section of this old sea cliff preserved in the Tapeats sandstone in the southern wall of Hotauta Canyon near the Colorado reveals clearly every detail of the structure; at the base of the cliff huge angular blocks of Shinumo quartzite are incorporated in the Tapeats sandstone in the places where they fell and lodged; farther out lie masses of bowlders, worn and rounded by the pounding of the waves; and these bowlders run into lenses of fine pebbly conglomerate, representing the shingle of the ancient beach, dragged out by the undertow. No more striking example of a fossil sea cliff can be imagined.

BRIGHT ANGEL SHALE.

The name of the Bright Angel shale is derived from Bright Angel Canyon, in the walls of which the formation is well exposed.

The section following was measured on the north side of Colorado River between Hakatai and Burro canyons, in the central part of the Shinumo quadrangle.

Section of Bright Angel shale on north side of Colorado River between Hakatai and Burro canyons.

A. Upper division (alternating layers of shale and purplish-brown sandstone in upper part; soft, greenish, micaceous sandy shales below; the lower part makes a moderate slope and the upper part a steep slope):

	Feet.
1. Shale	16
2. Sandstone	2
3. Shale	16
4. Sandstone	3
5. Shale	6
6. Sandstone	1
7. Shale	5
8. Sandstone	2
9. Shale	80
	131

B. Middle division (locally known as "Snuffy limestone"; two cliffs of resistant limestone separated by a slope of soft shale; see Pl. XVIII, p. 86):

1. Dense snuff-colored limestone, somewhat sandy, with platy partings	10
2. Very dense, snuff-colored crystalline limestone	12
3. Soft shales, including a very thin layer of glauconite (?) containing linguloid brachiopods	25
4. Limestone like 2	10
	57

C. Lower division (soft, green, micaceous sandy shales with occasional thin layers of resistant sandstones, which form small cliffs; the entire division makes a very gentle slope):

1. Cross-bedded greenish sandstone	6
2. Extremely soft shales with a few very thin interbedded layers of fossiliferous sandstone and phosphatic limestone, made of the shells of linguloid brachiopods. A layer of glauconite (?) a few inches thick occurs in the center of the shales.	75
3. Sandstone, containing fossils	1
4. Shale	7
5. Sandstone	2
6. Shale	9
7. Cross-bedded brown sandstone, containing fossils	3
8. Shale	55
9. Reddish-brown quartzite, in many places conglomeratic	2
	160
Total thickness of Bright Angel shale	348

Most of the fossils were found in certain layers of brown sandstone, indicated in the section, but some were collected from the shales, through which fossils are also scattered, though much less abundantly. All the specimens found in the sandstones bear marks of grinding and attrition.

The following forms were identified: By Prof. Schuchert: Worm trails; *Lingulepis spatulus; Lingulella acutangula.* By Mr. Walcott: *Obolus westania*, var. *themis.* By Mr. Bassler: Phyllopod—*Indiana faba* U. and B.

In addition, Mr. Walcott collected at the same horizon in the Shinumo quadrangle in 1901 numerous worm trails, *Lingulella limolata, Lingulella perattenuata*, and *Lingulepis spatulus.*

These fossils show that the Bright Angel shale is of Middle Cambrian age. Whether the underlying unfossiliferous Tapeats sandstone represents the Middle or the Lower Cambrian system is not yet known. Walcott[1] thinks it probable that the erosion interval represented by the unconformity at the base of the Tapeats sandstone represents the whole or a large part of the Lower Cambrian.

The Bright Angel shale, like the formations of the Unkar group, is characterized by curious circular or elliptical spots that appear throughout all the shaly and sandy strata, some caused by local leaching, some by local addition of a ferruginous mineral.

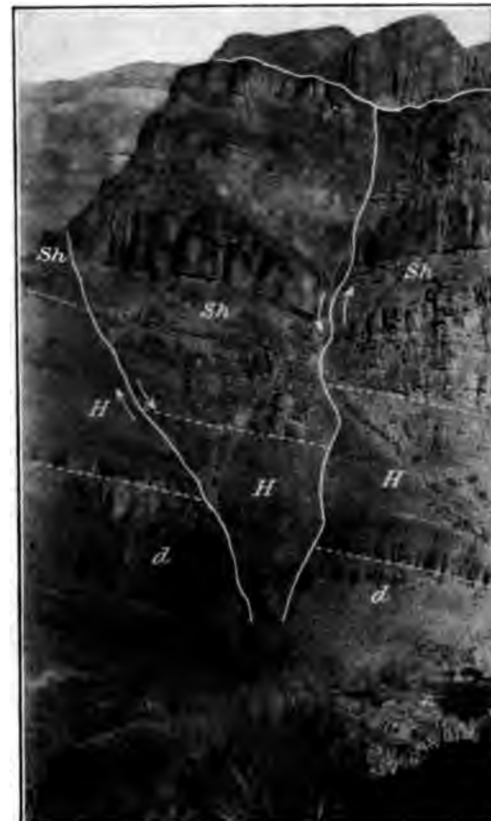
MUAV LIMESTONE.

The name of the Muav limestone is derived from Muav Canyon, in the lower part of which the formation is particularly well exposed. (See Pl. XV, *A.*) It designates the predominantly calcareous part of the Tonto group.

The limestones of the formation are of a peculiar and distinct type. Characteristically, they are impure thin-bedded bluish-gray limestones which have a mottled appearance, imparted by infinitely numerous thin bands or lenses of buff or greenish shaly material. By this mottling and the thin banding the formation can be readily distinguished at a distance. On closer inspection the limestones are seen to contain numerous imperfect coralloid or fucoidal markings. The upper part of the formation contains layers of sandstone and some layers of massive buff crystalline limestone, but most of the beds are slightly impure and mottled. The shaly material of the mottlings is locally finely micaceous, and in places the rock comprises more shale than limestone. In other places the formation contains layers that have the appearance of a shale conglomerate, made up of rounded, flattened fragments of shale and limestone. Some of the fucoidal mottlings are composed of buff or green shale and some layers of the limestone are cherty. Infinite variations of all phases occur throughout the formation. The sandstones and the purer portions of the limestones make cliffs and the impure portions make slopes. The upper part of the formation unites with the layers at the base of the overlying Redwall limestone to form the lower part of a single great cliff.

[1] Walcott, C. D., Pre-Cambrian igneous rocks of the Unkar terrane: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, p. 518, 1894.

A. MUAV LIMESTONE IN MUAV CANYON.



B. FAULTS IN UNKAR WEDGE IN CANYON OF SHINUMO CREEK.

The wedge outlined includes 1,000 vertical feet of strata. ***d***, Diabase; ***H***, Hakatai shale; ***Sh***, Shinumo quartzite.

The following section was measured in Bass Canyon:

Section of Muav limestone.

	Feet.
Massive layers of buff crystalline limestone (cliff)	30
Fine-grained calcareous buff sandstone (cliff)	90
Sandy mottled limestone (steep slope)	85
Fine buff sandstone	5
Mottled limestone (cliff)	200
Impure shaly mottled limestone, fine-grained buff sandstone, and snuff-colored crystalline limestone in thin laminæ	45
	455

No fossils were found in the Muav limestone in the Shinumo quadrangle. The similarity in lithologic character, however, leaves little doubt that the beds are the same as those of the "mottled limestone" (earlier nomenclature), from which Walcott collected an abundant Middle Cambrian fauna both in Kanab Canyon, farther west, and in the eastern part of the Kaibab division.

CORRELATION OF TONTO GROUP.

According to Ransome,[1] the Tapeats sandstone is apparently equivalent to the Apache group of the Globe district, to the Coronado quartzite of the Clifton district, and to the Bolsa quartzite of the Bisbee district. The Bright Angel shale and the Muav limestone are apparently represented by the Abrigo limestone of the Bisbee region.

UNCONFORMITY.

In certain parts of the Grand Canyon, both east and west of the Shinumo quadrangle, the Cambrian Muav limestone is separated from the overlying Carboniferous Redwall limestone by a peculiar unconformity of erosion without unconformity of dip. The studies that revealed the presence of this unconformity were made by Walcott.

In Kanab Canyon, 20 miles west of the Shinumo quadrangle, Walcott[2] reports the presence of Devonian beds separated by a strong line of erosion from the underlying Cambrian and by a similar line of erosion from the overlying Redwall. The writer had the privilege of examining sketches made by Mr. Walcott showing the details of these unconformities. In one place canyons 80 feet deep were eroded in the "mottled limestone" (Muav limestone) and these depressions were filled by limestones and sands containing a Devonian fauna.

[1] Ransome, F. L., A comparison of some Paleozoic and pre-Cambrian sections in Arizona: Science, new ser., vol. 27, p. 69, 1908.

[2] Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Arizona: Am. Jour. Sci., 3d ser., vol. 20, pp. 221-225, 1880.

The observations of Walcott at the east end of the Kaibab division reveal a similar condition. He writes:[1]

In places the Devonian is entirely absent, either through erosion or nondeposition, so that the Redwall limestone rests directly upon the massive calciferous strata of the upper Tonto. It rarely has a thickness of more than 100 feet.

In the south wall of the Grand Canyon between Ruby Canyon, in the Shinumo quadrangle, and Pipe Creek, in the Bright Angel quadrangle, the unconformity between the Muav limestone and the Redwall is well marked and in many places Devonian beds lie in small hollows eroded in the Muav limestone. These Devonian beds are clearly separated from the underlying Muav and from the overlying Redwall by unconformities of erosion. In the Shinumo region, however, this double unconformity is not clearly evident, and in order to determine the stratigraphic relations in Bass Canyon with certainty it will be necessary to trace the beds at the horizon of the unconformity westward from Ruby Canyon into the Shinumo region.

CARBONIFEROUS SYSTEM.

REDWALL LIMESTONE.

The type locality for the Redwall formation is Redwall Canyon, in the Shinumo quadrangle. The name was applied to the formation long ago by Gilbert.

Because of the lack of fossils and the failure to detect the line of erosion that would mark a division between the Muav limestone and the Redwall in Bass Canyon it has been necessary to fix tentatively the base of the Redwall by means of lithology. The Muav limestone is here overlain by alternating layers of calcareous sandstone and dense blue-gray crystalline limestone, which have a thickness of 110 feet. These layers are taken arbitrarily as the base of the Redwall. The remainder of the formation comprises beds of pure, dense, bluish-gray crystalline limestone, the bedding of which is generally so obscure that they have the appearance of a single stratum. The bedding is thinner in the lower than in the upper part of this limestone. These beds of limestone appear in a single great cliff, the highest in the Grand Canyon. The face of the cliff is generally stained red by the weathering of the overlying red shales of the Supai formation. These obscurely bedded limestones are about 500 feet thick in Bass Canyon.

The cliff-making limestone of the Redwall formation has produced some of the most remarkable scenery in the canyon. Throughout the canyon the faces of the cliffs it forms are recessed with great niches and alcoves and are penetrated by many caves. The niches

---

[1] Walcott, C. D., Pre-Carboniferous strata in the Grand Canyon of the Colorado, Arizona: Am. Jour. *Sci., 3d ser.*, vol. 26, p. 438, 1883.

and alcoves are described, but left unexplained, by Dutton [1] and are explained by Davis.[2] Their grandest development in the region is found in the walls of Walthenberg Canyon, in the Shinumo quadrangle. Two of the largest caves in the Redwall are found in Bass Canyon and in the upper part of Muav Canyon.

The total thickness of the Redwall limestone in Bass Canyon is 610 feet, of which at least 30 feet at the base is probably of Devonian age.

The only fossils obtained in this formation by the writer were some obscure forms collected about 325 feet above its base in Bass Canyon. These comprise some cross sections of a cyathophylloid coral and some small brachiopods, which were identified by Prof. Schuchert as Schuchertella. They may belong to either a Mississippian or a Pennsylvanian fauna.

In Kanab Canyon, 20 miles west of the Shinumo quadrangle, Gilbert [3] found abundant fossils in the Redwall and concluded that the base of the formation in that locality represents "Lower Carboniferous" (Mississippian) and the summit "Upper Carboniferous" (Pennsylvanian) time, the transition taking place without break.

Similar evidence was obtained later by Lee [4] in the western part of the Grand Canyon region. The paragraphs presenting this evidence are here quoted:

In Truxton Canyon two small collections of fossils were obtained from the Redwall limestone. These were examined by G. H. Girty, of the Geological Survey, who reports the following lists:

At Yampai, near the top of the exposed section, the following were obtained:

- Derbya (?) sp.
- Composita.
- Aviculipecten.
- Myalina sp. aff. M. Meliniformis and M. cogeneris.
- Edmondia (?) sp.

These fossils, according to Girty, indicate a Pennsylvanian or "Coal Measures" age.

Lower in the section, near Nelson, Ariz., Mississippian forms were obtained, as follows:

- Menophyllum excavum.
- Schuchertella inequalis.
- Spirifer centronatus.
- Spirifer striatus var. madisonensis.
- Straparollus sp.

Girty states that this is the Eo-Mississippian fauna, which has a wide range over the West, correlating it with the lower "Wasatch limestone of Utah, the Madison limestone of Yellowstone Park, and the Chouteau limestone of Missouri."

Lee believes that in the locality described by him the upper part of the Redwall is Pennsylvanian and the lower part is Mississippian,

[1] Dutton, C. E., Tertiary history of the Grand Canyon district: U. S. Geol. Survey Mon. 2, chap. 14, 1882.

[2] Davis, W. M., An excursion to the Grand Canyon of the Colorado: Harvard Univ. Mus. Comp. Zool. Bull. 38, vol. 5, No. 4, p. 178, 1901.

[3] Gilbert, G. K., op. cit., p. 178.

[4] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, p. 15, 1908.

the line of division being drawn between the upper massive and the lower laminated members of the formation.

The fossils found by the writer of the present report in the lower part of the formation in the Shinumo quadrangle are apparently similar to forms found in the part of Lee's section which is referred to the Mississippian by Girty, but correlation can not be based upon evidence so doubtful.

The limestone beds in which Pennsylvanian fossils were found by Gilbert and Lee may be the correlatives of the layers of cherty limestone that lie at the base of the Supai in the Shinumo region, and the line of separation between the Mississippian and Pennsylvanian may consequently be the base of the Supai formation in Bass Canyon, but until this question has been decided by further study the base of the Redwall may be assigned to the Mississippian and the summit to the Pennsylvanian.

AUBREY GROUP.

All the strata above the Redwall limestone in the canyon wall belong to the Aubrey group. The group is divisible into three formations—the Supai, the Coconino, and the Kaibab.

SUPAI FORMATION.

Lithology.—This is the basal formation of the Aubrey group. The name was given by Darton[1] and is derived from the Indian village of Supai in Cataract Canyon, which is designated as the type locality. The Supai formation is easily distinguished by its color, for it contributes most of the red to the canyon landscape. Its upper part is made of soft red shale, which appears in a gentle, waste-covered slope beneath the Coconino sandstone cliff. Its lower part consists chiefly of layers of hard sandstone, which make a long, steplike succession of cliffs, each of which corresponds in height to the thickness of the bed that determines it. The shale of the upper part wastes back from the summit of the sandstone of the lower part and leaves the Esplanade platform. (See Pls. VI and VII, *A* and *B*, pp. 21, 22.)

Sandstone of the Supai formation.—The basal member of the lower division of the Supai formation in Bass Canyon, which is about 100 feet thick, consists of red shales alternating with beds of massive blue-gray crystalline limestone containing bands and nodules of red chert. These beds waste back from the summit of the Redwall, leaving a narrow ledge. The remainder of the lower division consists almost entirely of fine-grained cross-bedded sandstone. At a horizon 575 feet above the summit of the Redwall, however, some remarkable beds of limestone conglomerate are here and there interbedded with the sandstones. The conglomerate occurs in lenses, which alternate

[1] *Darton*, N. H., A reconnaissance of parts of northern New Mexico and northern Arizona: U. S. Geol. *Survey* Bull. 435, p. 25, 1910.

with beds of fine red shaly sandstone. The total thickness of the beds that carry the conglomerate lenses is 20 feet. The pebbles, which are derived from a rock of much the same character as the massive part of the Redwall limestone, are well rounded and their average diameter is about an inch. The matrix is red mud. The thickness of the sandstone division of the Supai formation is 850 feet in Bass Canyon and shows little variation in the quadrangle.

Shale of the Supai formation.—The upper member of the higher division of the Supai formation consists chiefly of soft red shaly sandstones, which make a slope rising from the Esplanade platform and are largely masked by fans of gray waste shot down from the overlying Coconino sandstone. In the walls directly above Bass Canyon the formation is 400 feet thick but its thickness varies greatly in the quadrangle.

The total thickness of the Supai formation in this locality is 1,250 feet.

In the Shinumo region the Supai formation appears to be separated from the underlying Redwall limestone by a slight unconformity of erosion. According to Darton [1] it is "distinct from the gray sandstone [Coconino] throughout northern Arizona, but their separation from the underlying Redwall is not everywhere so clear as could be desired."

COCONINO SANDSTONE.

Darton writes: [2]

> The name Coconino sandstone is proposed for the cross-bedded gray to white sandstone of the Aubrey group, which is so conspicuous in the walls of the Grand Canyon. It underlies the entire Coconino Plateau, as well as the extensive plateau country north of the Grand Canyon.

The Coconino sandstone is buff to creamy-white, is of uniformly fine grain, and is characterized throughout by cross-bedding. It forms a single great, massive bed, which makes the highest cliff in the upper wall of the canyon, whose white color presents a striking contrast to the red color of the shales of the Supai formation in the slope beneath. The huge scale of the cross-bedding is remarkable. The inclined beds dip in a general southerly direction and each layer is evenly truncated above, so that it forms a wedge. Many of the wedges attain a thickness of 100 feet. No ripple marks or sun cracks have ever been found in the Coconino sandstone and, with the exception of the Tapeats sandstone, it is the only Paleozoic formation of the canyon wall in which fossils have not been found. Its thickness varies considerably in the quadrangle and is everywhere in inverse ratio to that of the underlying shale of the Supai formation. Under Havasupai Point, near Bass Canyon, its thickness is 335 feet.

---

[1] Darton, N. H., idem. [2] Darton, N. H., idem, p. 27.

KAIBAB LIMESTONE.

The name Kaibab has been applied to the next highest formation by Darton[1] from the fact that it forms the surface of the Kaibab Plateau. The Kaibab limestone overlies the Coconino sandstone and is the highest formation in the canyon wall. Upon it are developed the surfaces of all the plateaus of the Grand Canyon district. The upper portion of the formation consists of layers of dense buff or cream-colored limestone, which are composed largely of the remains of sea animals and contain great quantities of lumpy flint or chert. Fossil Mountain (Pl. VII, *B*, p. 22), near Havasupai Point, is so named because of the abundance of fossils on its southwest slope. The layers of limestone are very resistant to erosion and make the first cliff that drops away at the rim of the canyon. The middle and lower portions of the formation consist of beds of sandy limestone, which decay more easily and make a series of weak cliffs and steep slopes in the wall.

The unequal hardness of the upper and middle parts of the formation has produced a curious scenic feature in the north wall of the canyon. Rain erosion has carved the rock into colossal pillars or "hoodoos," which stand like sentinels along the rim of Shinumo Amphitheater (Pl. XVI, *A*, p. 78). Each pillar is preserved by a cap of the hard summit limestone, which protects the softer sandy limestone beneath.

The absence of surface streams on the Kaibab Plateau is due to the fact that its floor is made of limestone. As is usual in limestone regions of abundant rainfall, the rock is honeycombed by a system of underground drainage channels which have been dissolved by rain water that descends along lines of joint and fracture. In only a few places do the surface waters flow far before they sink and join this underground system, in which they continue southwestward with the dip of the strata and burst out as springs in the north wall of the canyon, feeding the perennial streams of the amphitheaters. The map shows small circular depressions here and there on the plateau. These are sink holes, each of which has in its bottom an outlet that communicates with the underground channels. Where the outlets become clogged up the sinks hold small ponds in wet weather. Fen Lake is one of these ponds.

Section of Kaibab limestone near Fossil Mountain, Coconino Plateau.

	Feet.
A. Crystalline limestone, containing many nodules of chert in its upper portion. The cherty layer caps the remarkable "pinnacles of erosion" along the northern rim of the canyon in the Kaibab division	75

[1] Darton, N. H., idem, p. 28.

		Feet.
B.	Very fossiliferous white crystalline limestone, forming a cliff...	200
C.	Bed of soft and crumbling calcareous sandstone, locally a conglomerate made up of fragments of soft calcareous sandstone.	20
D.	Calcareous red and white sandstones..........................	135
E.	Buff, crystalline, siliceous limestone, making a cliff............	40
F.	Calcareous white sandstone, making a ledge and slope at the summit of the Coconino sandstone..........................	50
		520

The fossils of division B are abundant wherever the beds of that horizon are exposed in the quadrangle. A collection made at Fossil Mountain and in the Muav Saddle was examined by G. H. Girty, of the Geological Survey, who reports that the forms comprise all those which are includad in a similar collection in his possession obtained at the same horizon in the Kaibab limestone at Parusi-Wompats Spring, just north of the Shinumo quadrangle, on the Kaibab Plateau.

The list from Parusi-Wompat is as follows:

Sponges.
Lophophyllum n. sp.
Crinoid stems.
Fistulipora sp.
Meekopora sp.
Stenopora sp.
Septopora sp.
Polypora sp.
Lingulidiscina convexa?
Derbya sp.
Meekella pyramidalis.
Chonetes aff. hillianus.
Productus occidentalis.
Productus ivesii.
Productus aff. irginæ.
Productus subhorridus var. rugatulus?
Productus sp.
Pugna osagensis var.
Heterelasma n. sp.
Squamularia guadalupensis?
Spiriferina campestris?
Composita subtilata.
Aviculipecten 2 sp.
Acanthopecten occidentalis.
Pseudomonotis aff. hawni.
Pseudomonotis? sp.
Anisopyge perannulata?

In a letter concerning this fauna Girty writes:

The list is typical of the fauna of the upper Aubrey, the general character of which has long been known through similar lists made up by Meek and others. I have been tentatively correlating the Aubrey with the Manzano group of New Mexico and with the upper part of the Hueco formation of western Texas. Consequently, it would be older than the Guadalupe group, which overlies the Hueco formation. The fauna listed above, however, contains a number of species which are very similar to or identical with species that occur in the Guadalupian fauna, and in spite of the fact that most of the Guadalupian species have not been found in the Aubrey group, it seems less improbable than it did several years ago, when the Guadalupian fauna was under investigation, that the Kaibab limestone is of the same geologic age.

VARIATION IN THE THICKNESS OF THE PALEOZOIC STRATA.

The table following shows the variations in thickness of the Paleozoic strata in the quadrangle.

Approximate thickness, in feet, of the Paleozoic formations in different parts of the Shinumo quadrangle and in Bright Angel quadrangle.

[The letters (as NE. NW.) after each locality indicate the part of the quadrangle in which it is situated.]

	Thompson Point (NW.).	Apache Point (W.).	Wheeler Point (NW. center).	Dutton Point, Masonic Temple (N. center).	Tyndall Dome (center).	Havasupai Point (center).	Point Sublime (E.).	Diana Temple, Topaz Canyon (SE.).	Monadnock Amphitheater (E.).	Maximum thickness in quadrangle.	Minimum thickness in quadrangle.	Bright Angel trail, in Bright Angel quadrangle.
Kaibab limestone	600	600	550	600	....	550	600	500	....	600	400	560
Coconino sandstone	250	300	300	250	....	335	250	350	....	350	250	385
Supai formation:												
Shale	550	550	550	450	....	400	400	300	....	550	300	260
Sandstone	850	....	850	900	....	850	850	950	....	950	850	930
Redwall limestone	700	....	....	700	625	....	....	625	625	700	600	550
Muav limestone	475	....	....	450	450	....	....	450	450	475	400	385
Bright Angel shale	375	....	....	375	350	....	....	325	25	375	25	325
Tapeats sandstone	275	....	....	280	285	....	....	235	0	285	0	265
Total Paleozoic system	4,065	....	....	4,005	....	....	....	3,735	....	....	....	3,660

The Kaibab limestone varies considerably in thickness from place to place, but this variation is only apparent, being due to the fact that the summit of the formation has undergone unequal erosion in different parts of the quadrangle. The original thickness was probably nearly uniform.

The Coconino sandstone decreases steadily in thickness toward the north and west.

The shale of the Supai formation increases steadily in thickness in the same directions.

The sandstone of the Supai formation varies only slightly, its thickness decreasing toward the west.

The Redwall limestone increases in thickness toward the north and west.

The Muav limestone becomes slightly thicker toward the west.

The Bright Angel shale is nearly uniform in thickness throughout the quadrangle except in places where the Unkar monadnock projects into it. Its texture becomes firmer toward the west.

The thickness of the Tapeats sandstone depends entirely on the relief of the underlying eroded surface and therefore shows an exceedingly irregular variation.

The total thickness of the Paleozoic system increases gradually toward the north and west.

EFFECT OF THE VARIATION IN THE THICKNESS OF THE PALEOZOIC STRATA UPON THE TOPOGRAPHY OF THE CANYON WALL.

The profile of the canyon wall in the Paleozoic strata everywhere shows a direct relation to the variations in thickness and character of the strata of this era. It has been emphasized that each resistant stratum makes a cliff and each weak stratum a slope, and that each ledge in the wall is made by the wasting back of weak strata from the summit of a resistant, cliff-making stratum below. The width of a ledge invariably increases with the thickness of the weak strata, and is also controlled by the relative thickness and strength of the overlying strata which defend the retreat of the wall above. Although this relation has always been recognized in the smaller ledges in the canyon wall, a different explanation of the two widest ledges, the Esplanade and Tonto platforms, is found in most geologic literature—an explanation based on a theory advanced by Dutton.

Dutton [1] explains the Esplanade (Pl. VI, p. 21) by a pause in the uplift of the region during the cutting of the Grand Canyon. By this pause a temporary base level of erosion was produced, the topographic expression of which was a mature valley whose floor was the Esplanade.

> Again the country was hoisted, this time more than before * * *. Swiftly the inner gorge was scoured out and the chasm assumed its present condition.

[1] Dutton, C. E., op. cit., p. 121.

The reader is led to infer that the Tonto platform (Pl. V, p. 20) represents the prolongation of the same base level into the Kaibab division.

The physiographic studies of Davis in the canyon region, however, have made it clear[1] that the Esplanade is associated with the same changes in character and thickness of strata that produced the smaller benches in the canyon; that the Esplanade may be regarded simply as a structural bench; and that it is not therefore necessary to postulate more than a single cycle for the cutting of the Grand Canyon.

The writer of the present report is entirely in accord with Davis. The Shinumo quadrangle is the critical area for the study of the origin of the platforms, for the profile of the canyon wall here changes from that which is characteristic of the Kaibab division to that which is characteristic of the Kanab. This change, which takes place opposite Havasupai Point, has already been described, and the variations in thickness and character of the Paleozoic strata have just been outlined. The perfect correlation of the character of the rocks with the topography in the two greatest platforms will now be shown.

In the Kaibab division the Bright Angel shale of the Tonto group is uniformly weak and has wasted back rapidly from the summit of the Tapeats sandstone, leaving the wide ledge known as the Tonto platform. As the Bright Angel shale is traced westward into the Shinumo quadrangle, layers of resistant snuff-colored limestone begin to appear in the middle of the formation. These layers, known locally as the "Snuffy limestone" (Pl. XVIII, p. 86), gradually increase in thickness toward the west, making two delicate parallel cliffs which form a conspicuous feature in the interior of the canyon. Similarly the overlying Muav limestone and the massive Redwall limestone become gradually thicker toward the north and west, and the innner canyon narrows as these strata become more and more effective in defending the retreat of the wall.

In the Kanab division the Supai formation of the Aubrey group consists of weak red shales in its upper portion and resistant sandstone below. The shales waste back from the summit of the sandstone, leaving the Esplanade platform. In the western part of the quadrangle, where the Esplanade is developed, the thickness of these shales is 550 feet, whereas that of the overlying massive Coconino sandstone, which defends the retreat of the outer wall, is only 250 feet. East of Havasupai Point, in the Kaibab division, the thickness of the shale of the Supai formation decreases to 300 feet, whereas

[1] Davis, W. M., An excursion to the Grand Canyon of the Colorado: Harvard Univ. Mus. Comp. Zool. Bull. 38, geol. ser., vol. 5, No. 4, pp. 181 et seq., 1901; An excursion to the Plateau province of Utah and Arizona: Harvard Univ. Mus. Comp. Zool. Bull. 42, geol. ser., vol 6, pp. 31 et seq., 1904.

that of the Coconino sandstone has increased to nearly 400 feet. The Esplanade fades to a narrow ledge in this part of the canyon.

If the Esplanade and Tonto platforms represent base levels of erosion there is no reason why every bench in the canyon wall should not represent a similar base level. In the Kaibab division at least two benches are better developed than the bench that locally represents the Esplanade. The writer agrees with the conclusions of Robinson, who, in discussing the same problem from observations made in the Bright Angel quadrangle, says:[1]

> It is hardly reasonable to expect such a nice adjustment of base levels, three or four in number, to suit definite structural horizons. It must be concluded, rather, that the benches are simply what they appear to be—the stripped surfaces of resistant formations which have been successively exposed in the progressive downcutting of the Colorado River through the plateau.

The facts that the Esplanade and Tonto platforms are both widely developed in the central part of the Shinumo quadrangle and that they are there vertically over 2,000 feet apart show that they do not represent a common base-level of erosion.

STRUCTURAL GEOLOGY.

WEST KAIBAB FAULT.

Perhaps the most interesting structural feature in the quadrangle is the West Kaibab fault, in the Muav-Flint canyon, where the line of the fault is laid open to study for a vertical mile by the deep cutting of the gorge, which has revealed three separate displacements along the same line. These displacements occurred at widely separated periods of geologic time. (See Pl. I, sections, in pocket.)

The earliest of these displacements is recorded in the pre-Cambrian rocks in the depths of the canyons of Shinumo and Flint creeks, and is the great fault that limits the Unkar wedge on the northeast, bringing up the Vishnu schist on the opposite side of the fault plane.

The strike of the fault in this part of the Muav-Flint canyon is in general northwest-southeast, but its extension is undulatory, as may be seen from the geologic map. The dip of the fault plane is 60° SW. in the only locality where a vertical cross section could be observed. The strata of the Unkar group are dragged up against the fault line throughout its exposure, the drag sharply reversing their usual northeasterly dip. The fault plane is marked by cemented breccia wherever it crosses the harder beds of the Vishnu schist or the quartzites of the Unkar group. Between the Dox sandstone and the Vishnu schist it is characterized by a soft talcose selvage.

The pre-Cambrian age of the fault is established by the fact that the entire structure is truncated by the base-leveled surface of erosion

[1] Robinson, H. H., The single-cycle development of the Grand Canyon of the Colorado: Science, new ser., vol. 34, No. 864, p. 90, 1911.

at the base of the Tapeats sandstone. The total amount of displacement can never be known; the highest beds of the Unkar group which abut against the fault belong to the Dox sandstone, lying stratigraphically 5,800 feet above the Archean surface upon which the Unkar group rests, but this can be only a minimum measure because of the truncation of higher beds by the pre-Tonto unconformity, as explained above.

The two later displacements which took place along the same line are recorded in the Paleozoic strata.

The earlier of these displacements is a monoclinal flexure, which dips northeastward. This flexure is clearly defined throughout the Muav-Flint Canyon, from Muav Saddle to the gap between Point Sublime and Sagittarius Ridge, a distance of 10 miles, in which it displays everywhere about the same amount of throw and the same radius of curvature. The throw ranges from 400 to 500 feet and the curvature is accomplished within a quarter of a mile. Southeast of Point Sublime the flexure diminishes in throw to about 50 feet and crosses the river near the eastern boundary of the quadrangle at the mouth of Slate Creek. Boucher trail, in the Bright Angel quadrangle, ascends the canyon wall for a part of the way in the line of the flexure.[1] The course of the displacement north of Muav Saddle is described on page 79.

The deep Muav Canyon affords an excellent opportunity to study the effect of folding in the Paleozoic beds. The beds of the massive formations—the Kaibab limestone, Coconino sandstone, Supai formation (sandstone division), Muav limestone, and Tapeats sandstone—bend downward in a graceful arc. The entire Redwall limestone curves downward as a single stratum. The soft sandstones of the Supai formation and the Bright Angel shale, however, are greatly mashed and crumpled.

The later displacement is a fault along the line of flexure. In the upper part of Muav Canyon the strata west of the fault are dropped; farther down the canyon the fault dies out for about half a mile and reappears with the throw reversed, the strata this time dropping on the northeast side of the fault, which finally dies out under Point Sublime, at the head of the canyon of Flint Creek.

The compound displacement gives a peculiar profile to the walls of the Muav-Flint Canyon: On the northeast side of the canyons of Shinumo and Flint creeks the combined throw of the fault and flexure drops the Tonto platform 500 feet below the level at which it stands on the opposite side, but in the upper part of Muav Canyon the throw of the fault just compensates that of the flexure. (See Pl. I, sections, in pocket.)

[1] Davis, W. M., An excursion to the Grand Canyon of the Colorado: Harvard Univ. Mus. Comp. Zool. Bull. 38, geol. ser., vol. 5, No. 4, p. 165, 1901.

A description of this fault in Muav Saddle is given by Dutton,[1] whose observations, however, did not extend southward into the canyon. North of the Muav Saddle the fault crosses Tapeats Amphitheater and its throw increases greatly until it becomes the immense break which drops the strata nearly 2,000 feet to the west and forms the western boundary of the Kaibab Plateau.

The flexure probably originated when the Paleozoic rocks were buried under a considerable load of Mesozoic strata, for the thick and massive Paleozoic beds yielded by bending rather than by breaking, as is shown in Muav Canyon. This movement must have occurred not long after erosion began in the region and therefore early in Tertiary time. The fault that breaks the flexure may have occurred at any time after the greater part of the mass of the Mesozoic strata had been eroded away.

FAULTS OF THE UNKAR WEDGE.

In addition to the great fault that limits the wedge on the northeast, a large number of smaller faults traverse the Unkar strata. (See Pl. I, sections.) These faults are exceedingly numerous, there being in some places as many as 30 to the mile. The amount of displacement ranges from almost nothing up to 400 feet, but by far the greater number have a throw of less than 50 feet. Only those whose throw exceeds 50 feet are recorded on the map. The general trend of the faults is northwest-southeast, parallel to that of the limiting West Kaibab fault and to the strike of the strata. The fault lines are very crooked, owing to the fact that they traverse a rugged region (Pl. XVII, *B*).

All the faults are of the normal type and divide the strata into crustal blocks. At many places two fault planes dip toward each other, a vertical wedge of strata lying between them. The fault blocks and wedges are of all sizes, ranging from those included between the larger faults down to those formed by the innumerable faults of small throw. A cross section of one of the wedges is clearly exposed in the cliff of the west wall of Shinumo Canyon about half a mile above its junction with Burro Canyon. (See Pl. XV, *B*, p. 64.) Every detail of the wedge is revealed from its summit, where it is truncated by the pre-Tonto unconformity down to its apex, a vertical distance of 1,000 feet.

Where the fault planes traverse the harder strata they are characterized by fault breccia and slickensided surfaces. The breccia is usually cemented with milky quartz and in nearly all such places a small amount of copper has been deposited, so that the weathered fault planes have a greenish stain.

---

[1] Dutton, C. E., op. cit., p. 162.

In Bass Canyon a sharp monoclinal flexure has been formed in the Unkar strata as a result of a compressive force acting from the southeast. This flexure runs northeastward through Bass Canyon, crossing the Colorado just above the mouth of Hotauta Canyon. It has long been known to visitors as the "Wheeler fold." (See Pls. XVI, *B*, and XVII, *A*.) Its throw is about 300 feet. It is finely displayed in cross section in the wall of the Granite Gorge on the north side of the Colorado. Here the diorite that intrudes the Vishnu schist has been buckled and shoved into the limestones, shales, and jaspers of the lower Unkar and the flexure is passing into a thrust fault.

All these smaller faults, like the great limiting fault, are truncated by the pre-Tonto unconformity (see Pl. I, sections) and were likewise undoubtedly formed by the great crustal movements that uplifted the Algonkian mountains.

DISPLACEMENTS OF THE PALEOZOIC STRATA.

In addition to the West Kaibab faulted flexure a number of smaller displacements of various types are recorded in the Paleozoic strata.

Flexures.—A number of very gentle flexures run northwest-southeast parallel to the strike of the southwestward warping of the strata. All dip southwestward and are hardly more than slight swells upon the warped surface. The most prominent of these flexures may be traced through Powell Plateau, near the head of Walthenberg Canyon. It runs southeastward through the great butte of Redwall limestone that stands between Hakatai and Burro canyons, and is exactly on the line of strike of the Unkar monadnock. A similar swell may be detected in the strata between Fossil Mountain and Bass Camp. These swells are in the zone of maximum southwestward warping heretofore described, and many similar swells may be detected in the quadrangle.

Faults.—In this part, as in other parts of the Grand Canyon, a number of minor faults are found which have no apparent relation to the greater lines of displacement that bound the blocked plateaus. They are haphazard in trend, have small throws, and most of them persist for only a few miles. The long straight gorge of Slate Creek coincides with a fault of about 125 feet. Another fault of this character runs through Bass Canyon and has guided the erosion of that gorge. It is directly on the line of the Algonkian displacement known as the Wheeler fold.

At least two displacements in the adjoining Bright Angel quadrangle are on the line of Algonkian faults, and in each the throw of the Paleozoic displacement reverses that of the Algonkian fault. One of these is the well-known Bright Angel fault, in the canyon of Garden Creek; the other is a faulted flexure which runs southeastward across the quadrangle in the gorges of Phantom, Cremation, and

A. PINNACLES OF EROSION IN KAIBAB LIMESTONE ALONG RIM OF KAIBAB PLATEAU.

These pinnacles or "hoodoos" are characteristic features of the scenery along the north rim of the Grand Canyon in the Kaibab division. They are carved in the Kaibab limestone by rain erosion. Each column is capped by a portion of the resistant cherty layer at the summit of the formation, which protects the softer and more easily eroded beds beneath. Although the cherty layer is also present on the south side of the Grand Canyon, the pinnacles are rarely formed there, for the rainfall is less.

B. WHEELER FOLD IN BASS CANYON.

View down Bass Canyon from summit of Tapeats sandstone. The strata in the fold are beds of the Bass limestone. The fold is overlain uncomformably by the Tapeats sandstone, which appears in the upper right corner of the view.

A. NEAR VIEW OF WHEELER FOLD FROM BED OF BASS CANYON.

Photograph by N. W. Carkhuff.

B. FAULTING IN STRATA O[illegible]HE UNKAR [illegible] BURRO CANYON

d, D[illegible]ase intrusive; *H*, Hakatai shale; *Sh*, Shinumo quartzite; T, T[illegible]; BA, Bright Angel [illegible]; *Sn*, "Sn[illegible]" limestone [illegible] Bright Angel shale; M, M[illegible]; R, R[illegible] limestone. Photograph by N. W. Carkhuff.

Grapevine creeks and limits the mass of Algonkian strata at the mouth of Bright Angel Creek in the same way that the West Kaibab fault limits a similar mass in the Shinumo region. This displacement is the northwestern extension of the great flexure that bounds the Coconino Plateau on the northeast and is known as the Coconino fold. If to these are added the Butte fault on the line of the East Kaibab monocline in the Vishnu quadrangle it becomes apparent that the reopening of a line of displacement after the lapse of a very long time is common in the Grand Canyon district.

The faults in the Grand Canyon have exerted a marked influence on the topography, as they form lines of weakness which, under the searching action of erosion, have determined the location of side gorges, such as the lateral gorge of the Muav-Flint canyon and the gorges between Sagittarius Ridge and Point Sublime, on the line of the West Kaibab fault. North of the Muav Saddle, beyond the boundary of the quadrangle, a similar lateral gorge in the line of the same fault runs northward entirely across the head of Tapeats Amphitheater, at right angles to the main course of Tapeats Creek, the master stream. Examples of the same phenomenon in the Bright Angel quadrangle are the canyons of Monument, Horn, Garden, Bright Angel, Phantom, and Cremation creeks and the upper part of the canyon of Grapevine Creek. Among other examples in the Vishnu quadrangle are Red Canyon, the canyon of Vishnu Creek, and the gorges in the line of the Butte fault.

Lines of fracture without displacement.—In addition to the faults the lines of fracture in the Shinumo quadrangle (and presumably in other parts of the canyon) have exerted a marked influence on the topography, although their importance has not been recognized in the literature of the Grand Canyon. In tracing many of the side gorges of the Grand Canyon to the walls at their heads the writer found in the Paleozoic strata lines of shattering that were directly on the main axes of the gorges. These lines of fracture can not be classed as faults, for they exhibit no appreciable throw, yet along each of them a sufficient amount of shattering has taken place to constitute a line of weakness, which has guided the erosion of the gorge.[1] The peculiar arrangement of the drainage lines of the Shinumo Amphitheater, heretofore described, affords a striking example of this phenomenon, for Merlin Abyss and the similar parallel lateral gorge that crosses the amphitheater between Lancelot Point and Elaine Castle lie along lines of fracture, and many other examples occur in the quadrangle.

Many of the buttes and temples in the Grand Canyon owe their isolation to lines of fracture. Elaine Castle is a good example, and

[1] Mr. François Matthes, of the Geological Survey, made an extensive study of these fracture lines in the Kaibab division several years ago and reached the same conclusions as to their significance.—Oral communication.

another is the great butte, capped by sandstone of the Supai formation, which forms the north arm of Monadnock Amphitheater. Among other examples are Explorers Monument, at the south end of Marcos Terrace, and Castor, Pollux, Diana, and Vesta temples, along the rim of the Coconino Plateau.

GEOLOGIC HISTORY.

THE SEDIMENTARY AND EROSIONAL RECORD.

The earliest decipherable record of the geologic history of the Shinumo quadrangle—a blurred and mangled record—is found in the Vishnu schist. Far back in geologic time a thick series of more or less arkose sands and muds was accumulating upon the subsiding floor of a great mediterranean sea. So much may be reasonably inferred from the mineralogic character of the quartz-mica and quartz-hornblende schists of the Vishnu formation. So dim and vague is the record that the base of the series, the floor upon which it was laid down, its thickness, and the location of the land mass from which it was derived must perhaps remain forever unknown. After a long period, in which sediments were accumulated and buried, a mountain-making movement wrote its story across the older manuscript in a later and bolder hand, blurring the ancient chronicle with a record of deep-seated regional metamorphism and imparting to the manuscript the aspect of a palimpsest. The regional metamorphism is conceived to have been brought about by deep burial of the sediments and by their subsequent folding and compression, which in slow process of time engraved upon them the characters of recrystallization and schistosity and were accompanied by their elevation into lofty mountains. Somewhat later the cores of these mountains were penetrated and their summits were farther uplifted by intrusions of great masses of igneous rock, here becoming quartz diorite, the injection of which was followed by injections of magma of pegmatite. Doubtless while this mountain-making movement was still in progress the forces of denudation were already at work, beginning a cycle of widespread erosion, which was carried through to a remote end and which planed away the ancient mountains to their bases and reduced hard and soft rocks alike to a flat, unbroken plain. This ancient surface is represented by the unconformity at the base of the Unkar group and marked the final cycle of this great unknown and unnamed eon of Archean time.

The next event is the beginning of another great cycle of sedimentation, which resulted in the deposition of the Grand Canyon series, of Algonkian age. This cycle was ushered in by the invasion of the land by a shallow sea, which swept over the featureless surface of the Vishnu plain.

The Hotauta conglomerate, at the base of the Unkar group, was the first formation deposited in this sea and was made from the mantle of loose rock and soil that covered the surface of the plain. The lithology of the formation is a possible clue to the climate of that time. Its lack of chemical weathering, locally shown by the freshness and the arkose nature of its component fragments and the red color of its matrix, indicating a lack of vegetation and of abundant moisture to decompose the soil and to reduce the iron which imparts to it its red color, point, to an arid climate. It is therefore possible that the Vishnu plain was a vast desert at the incoming of the sea. The lack of transportation, sorting, and rounding of pebbles in the Shinumo region indicates that the waves had little chance to rework the soil mantle. It seems impossible to account for these phenomena except by supposing a sudden invasion of the sea across the Vishnu plain. If we seek to interpret the past in the light of the present our only means of gaining an understanding of the conditions that then existed is to try to picture some present condition on the earth which is comparable with that preserved in the geologic record. A possible clue may lie in the present conditions about the Caspian Sea, where there is a desert that lies below the present level of the Black Sea, so that a sudden rise in the level of the ocean might cause that sea to overflow the low barrier which separates it from the Caspian and suddenly inundate the desert.

The succeeding Bass limestone was deposited in a permanent body of water into which mud was frequently washed. The section of this formation shows that the alternations in the character of its beds are almost innumerable. The exact cause of these alternations is unknown and is still a subject of speculation. Possibly they were due to climatic oscillation, for a change from an arid to a semiarid climate would load the rivers with sediment and arid intervals would retard their flow or dry them up entirely, resulting in a temporary clarifying of the sea and the deposition of limestone. Whether these limestones were formed by organic agencies or by purely chemical precipitation is also a matter of speculation, as the rocks contain no traces of life. The water was probably for the most part shallow, for sun cracks appear in the shales in the upper part of the member below the highest limestone stratum.

The most striking feature of the Hakatai shale is the great abundance of sun cracks in the shaly strata and of ripple marks and of cross bedding in the sandstones. Research by Prof. Joseph Barrell has shown that extensive sun cracking is most likely to be preserved on broad flood plains or deltas in an arid climate.[1] In the opinion of

[1] Barrell, Joseph, Relative geological importance of continental littoral and marine sedimentation: Jour. Geol., vol. 14, pp. 524-568, 1906.

the writer of the present report the extreme abundance of these cracks in the formation is hard to account for except by postulating wide delta flats or flood plains. Furthermore, the bright-red color of the shaly strata, taken in connection with the mud cracks, seems to bespeak an arid climate, with little or no vegetation to reduce the iron. It is certain that the Hakatai shale was deposited in very shallow water, which often evaporated entirely, leaving broad mud flats exposed to a hot sun. In the upper part of the formation, as may be seen from the section, the alternations of shale and sandstone are notably regular. The sandstone layers are composed of fine, cleanly sorted, and rounded quartz grains and are ripple marked and cross bedded, and the shales were a fine red mud. The cleanness of the sandstone in this alternating series is probably a mark of climatic oscillation. A climatic movement toward a wetter climate, if increasing the ratio of run-off to erosion, causes the rivers to flow on a lower grade and to sweep seaward the piedmont deposits of sand and gravel, and as the clay was largely sorted from those deposits when they were first laid down, their redistribution and their secondary sorting on a delta surface or sea bottom would be marked by extreme cleanness.

Great thickness, clean sorting, and extreme fineness and roundness of grain are the characters that distinguish the Shinumo quartzite, which is composed entirely of sandstones and quartzites. Most of the beds show cross bedding and ripple marks, bespeaking shallow water. Clean sorting and extreme fineness indicate long transportation, so the rivers that carried this material to the sea may have flowed through a great desert of dune sands, picking up and carrying material such as is to-day deposited in the delta of the Indus from a similar source. Scattered lenses of fine conglomerate within some of the strata suggest scoured and filled stream channels.

The Dox sandstone, again, bears all the marks of shallow-water origin; it is throughout characterized by mud cracks, ripple marks, and cross bedding. The addition of micaceous material and of some feldspar gives a slightly arkose character to the rocks; so possibly a crustal movement rejuvenated the land mass that supplied the sediments. Here, again, are marks of aridity, seen in the vermilion color and the vast development of mud cracks.

In the Shinumo quadrangle all subsequent Unkar and Chuar deposits have been removed by the truncation of the pre-Cambrian structure by the plane of the base-leveled surface of erosion beneath the Tapeats sandstone. In the Vishnu quadrangle, where these subsequent deposits are preserved, they also bear evidence of deposition in shallow water. It is not unlikely that a considerable portion of the Grand Canyon series was deposited in deltas or in the flood plains of rivers. The evidence obtainable from the Unkar group in

the Shinumo region indicates that an arid climate prevailed at least during the greater part of Unkar time.

The predominance of clastic sediments in the part of Walcott's section in the Vishnu quadrangle that corresponds to the Bass limestone in the Shinumo quadrangle suggests that the Vishnu region was nearer the shore line of the early shallow sea. The close correspondence in the lithology of the succeeding formations in both regions indicates uniform conditions of deposition over at least the distance between these quadrangles.

The next event that can be deciphered in the geologic record in the Shinumo quadrangle is the invasion of the Unkar strata by sheets of diabase. If these invasions are to be regarded as contemporaneous with the lava flows of the Vishnu quadrangle, they must have taken place before the deposition of the Chuar strata, which are assumed to have once overlain the Unkar group in the Shinumo region.

After at least 12,000 feet of Unkar and Chuar strata had accumulated, a mountain-making movement of block faulting and tilting, accompanied or succeeded by elevation, broke the Algonkian strata into great crustal blocks, which must have formed high ranges of mountains. Doubtless these mountains were in character and aspect at one time not unlike the faulted ranges of the Great Basin or the desert ranges of Arizona and California at the present day.

Then began a second long period of erosion that gnawed slowly but surely into these faulted mountains, reducing them in slow process of time through stages of youth, maturity, and old age, and finally eating down into the Archean rocks beneath and planing away all but the stumps of the faulted mountains, leaving the broad expanse of a base-leveled surface. This surface is the spectacular unconformity at the base of the Paleozoic. The remnants of the tilted and faulted Algonkian strata were left inset as wedges in this plain of Archean rocks. The monotony of the surface was broken here and there by a monadnock of Shinumo quartzite, which resisted the forces of erosion in that ancient plain by the same adamantine hardness by virtue of which these strata to-day wall in the deep box canyon of the Shinumo. These monadnocks of the Cambrian plain may be compared with the Baraboo ridges of Huronian quartzite, which by virtue of their homogeneity and hardness still stand as prominences that have weathered repeated cycles of erosion. This cycle of erosion was probably not completed until Cambrian time.

The next notable event in the region is the sinking of the plain and the incoming of the Tonto sea, which probably spread over a surface that strongly resembled the present surface of the great Laurentian peneplain of Canada, with its broad areas of crystalline rocks, in which are inset occasional blocks of sedimentary strata, and above which stand scattered monadnocks of quartzite.

The Tapeats sandstone is a deposit formed on the beach of the invading sea. When the sea came in over the ancient plain the mantle of rock waste that covered the surface was ground and reworked by the waves until only its most durable particles remained, making a quartz sand. The conglomerates in the basal part of the formation represent the coarse shingle of the beach, worn and rounded by the pounding of the waves; the grits and sandstones are the shifting sands along the ancient shore. The monadnocks of Shinumo quartzite stood as islands in the sea. The striking record of marine planation revealed in the cliff faces of these monadnocks has already been described.

After the deposition of the Tapeats sandstone, quantities of micaceous sand were washed into the gradually deepening sea. These sands formed the Bright Angel shale. Twice during this epoch the sea became locally clear and the layers of the so-called "Snuffy limestone" were deposited. The highest islands of quartzite of the Unkar group were finally buried by the uppermost sands of the Bright Angel shale. The fossils found in the Bright Angel shale are the first clear evidence of life in the Paleozoic sea; the fauna of Middle Cambrian age which they represent belongs far down in the scale of the world's life history.

After the deposition of the Bright Angel shale the sea became clearer and the Muav limestone was laid down. Small quantities of mud were still being washed into the sea, imparting to the limestone its mottled appearance.

Then followed an interval in regard to which the record is nearly silent—a period lasting through Silurian and Devonian time. During the first part of that period the sea retreated and the upper part of the Muav limestone was exposed to erosion, probably as a low-lying land. During the Devonian period the sea came in over this land and deposited material that formed sandstone and limestone. Again the land was gently uplifted without deformation and was subjected to erosion which removed nearly all the Devonian strata except those that lay in depressions in the Muav limestone. So much may be learned from the study of the unconformity at the base of the Redwall limestone in the Grand Canyon region.

The next recorded event, coming in early Carboniferous (Mississippian) time, is a submergence in a sea that first received deposits of material that formed sandstone and limestone but rapidly became clear, depositing material that formed the massive Redwall limestone. The purity of this limestone is evidence of the clearness of the waters, and the presence of large cup corals indicates that the sea was warm.

After the deposition of the Redwall limestone the sea became very shallow, and into it large quantities of sand and mud were alternately washed. These sands and muds are the alternating red shales and

sandstones of the Supai formation, the lowest of the Aubrey group of strata. In some parts of the Grand Canyon region the sea was clearer and layers of limestone are there interbedded with the shales and sandstones of the lower part of the formation. A fauna of late Carboniferous (Pennsylvanian) age lived in that clearer portion of the sea. It is probable that the pebbles of the limestone conglomerate in the sandstone division of the Supai formation of the Shinumo region were derived from these limestones by erosion.

The origin of the overlying Coconino sandstone is an interesting problem. A counterpart of this formation in the Plateau province is the great sandstone 50 miles north of the Shinumo quadrangle, in the terraces of southern Utah, to which Huntington and Goldthwait have given the name Colob sandstone. The origin of this sandstone is discussed by Huntington and Goldthwait as follows:[1]

> The white sandstone is cross-bedded on a scale so large that a single layer attains a thickness of from 5 to 50 feet. * * * Everywhere the deposit consists of uniformly fine white sand without a trace of pebbles or coarser sand so far as has yet been observed. The uniformity of texture is emphasized by the total lack of ripple marks, which, as Cornish has shown, result from the mixture of sand grains of different sizes. That such a formation could be due to marine or lacustrine action of any kind seems contrary to what we know of such agencies. It is generally recognized that cross-bedding of a marked type is a proof that the deposits were formed close to the shore or on land. The uniform thickness of the Colob sandstone over so great an extent renders it antecedently improbable that it is a shore deposit; the total absence of ripple marks, rill marks, and other characteristic shore features lends support to this, and lastly the perfect smoothness and horizontality of the planes which truncate the tops of the strata render this still more improbable. * * * The same facts of structure, together with the total absence of gravel, of fossil stream beds, and of lateral unconformities render it equally improbable that the Colob was deposited by fluviatille processes. The only remaining possible agent is the wind. We can not yet be certain that the Colob sandstone is a wind formation; nevertheless none of its characteristics seem to oppose such an hypothesis. The uniformity and fineness of the component quartz grains, the steepness of the cross bedding, its general uniformity with interesting minor variations, the even truncation of the successive cross-bedded strata, and the tangency of the overlying layers to the plane surface thus formed suggest a series of great white dunes marching forward to the east and south from the base of the Basin Range Mountains. * * * It seems to be a fair question whether the cross-bedded strata of the Kanab and Colob formations may not be continental deposits laid down by the wind.

The Coconino sandstone differs little, except by its lesser thickness, from the sandstone just described, and many beds of sandstone in the underlying Supai formation resemble the Coconino sandstone, but are still smaller. It seems probable that whatever may have been the origin of these sandstones it must have been analogous to that of the sandstone of southern Utah described by Huntington and Goldthwait. If their interpretation is correct the region must have become land during the deposition of the Coconino sandstone and at

[1] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Mus. Comp. Zool. Bull 42, geog. ser., vol. 6, No. 5, pp. 214 et seq., 1904.

intervals during the deposition of the Supai formation, and the sandstones represent deposits of dune sand.

Again the sea invaded the land and laid down the sandy, calcareous sediments forming the base of the Kaibab limestone. The clarifying of the sea resulted in the deposition of the pure and richly fossiliferous limestones in the upper part of the formation. The fossils represent the typical fauna of the western sea in Pennsylvanian time. Life was easy, for the forms are fat and well nourished, as well as exceedingly abundant. The waters were probably shallow and warm as well as clear, for the rocks deposited in them contain great quantities of bryozoa, which possibly even formed reefs, and with the bryozoa are mingled the remains of echinoids, corals, crinoids, brachiopods, gasteropods, and sponges.

So much of the geologic history may be read from the actual rock record in the Shinumo quadrangle.

One who looks across the broad plateaus on either side of the Grand Canyon finds it difficult to realize that the deposition of strata did not end with that of the Kaibab limestone, upon which he stands, but the cliffs and terraces that rise to higher and higher levels along the northern border of the Grand Canyon district, as well as Echo Cliffs, on its eastern border, represent the eroded edges of strata that were once deposited horizontally bed upon bed upon the Kaibab limestone and that once extended continuously across the whole region where the Grand Canyon lies.[1] At the base of the cliffs on the north lie strata of the Permian epoch, completing the record of the Carboniferous and also of the Paleozoic; above lie strata of Mesozoic age—Triassic, Jurassic, and Cretaceous. The highest beds belong at the base of the Tertiary.

After the deposition of the Kaibab limestone, the accumulation of the Mesozoic and Tertiary strata went on quietly and almost continuously. The presence of occasional unconformities of erosion without unconformity of dip shows that whatever uplifts occurred were unattended by horizontal deformation. The strata were deposited "with almost rigorous horizontality."[2] By the end of Mesozoic time these strata had accumulated to a thickness considerably greater than that of the entire Paleozoic section of the canyon wall.

During the early part of the Tertiary period, after the accumulation of 6,000 feet or more of strata, deposited bed after bed above the Kaibab limestone, the Grand Canyon district began to be uplifted high above the surrounding country, and a period of erosion was begun which has lasted to the present day. This erosion was not continuous; there were pauses in the uplift of the region, during which the forces of erosion worked far along toward producing a mature topography;

---

[1] Dutton, C. E., op. cit., pp. 61 et seq.

[2] Dutton, C. E., idem.

GEOLOGIC HISTORY OF THE SHINUMO QUADRANGLE AS REVEALED BY THE LITHOLOGIC RECORD IN THE CANYON WALL.

V, Vishnu schist; *Au*, Unconformity, separating the Archean and Algonkian systems; *B*, Bass limestone; *H*, Hakatai shale; *d*, Diabase (intrusive); *Sh*, Shinumo quartzite; *Pu*, Paleozoic unconformity, separating Algonkian and Paleozoic rocks; *T*, Tapeats sandstone; *BA*, Bright Angel shale; *Sn*, "Snuffy limestone" in Bright Angel shale; *M*, Muav limestone; *R*, Redwall limestone; *Ss*, sandstone of Supai formation; *Ssh*, shale of Supai formation; *C*, Coconino sandstone; *K*, Kaibab limestone. A vertical mile of strata is in view. Photograph by N. W. Carkhuff.

then again the country would rise and the attack be renewed more vigorously. Out of all these vicissitudes of uplift and erosion two major cycles stand clearly forth, and the result of the work in each is stupendous.

The work of the earlier ana greater cycle is known as the "great denudation." As a result of the erosion in this period nearly all the 6,000 feet of Mesozoic and basal Tertiary strata was removed from the surface of the Grand Canyon district, their edges retreating to a line 50 miles north of the Shinumo quadrangle, to the cliffs along the border of Utah. Toward the end of the great denudation the surface of the region was reduced to a base-level of erosion. Fragments of this peneplain are preserved beneath the San Francisco Mountains, Red Butte, and the hills of the Uinkaret Plateau by floods of lava that were poured out upon the plain during the last stages of its formation. This resistant lava has protected the underlying strata from subsequent erosion.

The work of the second and lesser cycle is the cutting of the Grand Canyon by Colorado River and the removal of whatever remnants of soft strata were left upon the surface of the plateaus at the end of the great denudation. This cycle, which is still in progress, is known as the "canyon cycle" of erosion.

The course of Colorado River across the region became established before the beginning of the uplift which began the canyon cycle of erosion. As the land rose the river entrenched itself in its original course, continuing to cut deeper and deeper. The present stage of the valley is the Grand Canyon, which is thus wholly a product of erosion. It has been excavated by Colorado River and is deep, because the land is high and because in this arid region the river, fed by the snows of the Rocky Mountains, has cut down its bed much faster than the erosion due to strictly local agencies could lower the adjacent plateau. The walls have retreated slowly in comparison with those of most valleys, because the strata that determined them are unusually massive and because the forces that attacked them have been comparatively weak and have worked in the way characteristic of arid regions.

By far the most impressive feature of this wonderful country, to the traveler and the geologist alike, is the mile-deep pathway of the Colorado River of the West across the great plateaus. The stupendous and glaring record of erosion revealed in the cutting of this mighty gorge has almost blinded us to the immensity of the vastly greater record revealed in its walls (Pl. XVIII), but the erosion of the canyon becomes only an episode in the geologic history of the region in comparison with the story told by the two intersecting unconformities in the bottom of the gorge. These unconformities represent

two ancient cycles of sedimentation, uplift, and erosion carried to a remote end, separated by long intervals of time whose record is hopelessly lost, resulting twice in the planing down of lofty mountain ranges to their very cores, written vaguely at first on a blurred and time-worn record and later in an increasingly clearer and bolder hand, telling of the slow accumulation of the strata of the canyon wall on the floor of the Paleozoic sea, of the subsequently erased record of the accumulation of vast thicknesses of Mesozoic and Tertiary strata, at times separated by great intervals of erosion, and even telling of the "great denudation," which has stripped these later strata back 50 miles to the terraces of Utah—all these events representing a lapse of time which compared with that consumed in the cutting of the Grand Canyon is but as the passing of a summer afternoon compared to the procession of a season; for in the light of present knowledge according to the fossil record, it may be said that the Grand Canyon was all cut since man has inhabited the earth.

THE PLATEAU PROBLEM.

Since the history of the region from early Tertiary to the present time is entirely a record of uplift and erosion, that record should be interpreted wholly by means of the science of physiography. The salient events, as outlined above, were established beyond a doubt by the work of Dutton and Powell. The science of physiography, however, has grown remarkably since the work of these pioneer observers was done.

In 1900, 1901, and 1902 the region was visited by Davis,[1] whose studies confirmed the broader conclusions of Dutton, but brought to light evidence that the history of erosion in the region is far more complex than was formerly supposed.

It was shown that the great denudation was complicated by repeated movements of uplift, after each of which erosion may have reached an advanced stage.

It was discovered that the great displacements of the region began at an earlier date than was formerly supposed. The absolute antecedence of the Colorado River to the displacements, regarded by Dutton and Powell as proved, is therefore open to question.

It was made clear that the exact dates of the various events of the Tertiary and recent history are still unknown.

It was shown that these problems can be solved only by a great amount of further detailed observation, not only in the Grand Canyon district but in the neighboring regions.

Since the work of Davis, parts of the region have been studied in detail by Robinson, Huntington and Goldthwait, and Johnson,[1] and

[1] See Bibliography, p. 14.

many data bearing on these problems have been accumulated. Owing to the vastness and inaccessibility of the region a great amount of work of this kind still remains to be done.

The detailed interpretation of this complex erosional history has become known as "the plateau problem."

The most absorbing question of the plateau problem is that which concerns the date and the method of the establishment of the course of the Colorado River across the region. Two theories have been entertained.

The earlier theory is found in the writings of Dutton and Powell. These observers found that the general course of the river lies across the great lines of displacement that bound the blocked plateaus and were led to the conclusion that the course of the river was established before the first movements along the lines of displacement occurred. As the displacements came into existence the river continued to cut down in its original channel faster than they rose across its path. It was thought that the displacements did not begin until the end of the great denudation.

An alternate theory has been advanced by Davis and supported by Robinson, Huntington, and Johnson. The work of these men brought to light evidence that the first movements along the lines of displacement had begun early in the period of the great denudation; that the peneplain developed in the later part of this period represented a stage of erosion so far advanced that hard and soft rocks alike were reduced to a nearly even level and the initial relief produced by the displacements was almost effaced. The drainage system of the Colorado first became established upon this peneplain, the configuration of the surface of that time guiding the course of the river. The fact that the relief produced by the displacements was largely effaced in the peneplain would account for the course of the river across them.

In order to confirm this later theory that the Colorado is a superposed stream let down from the surface of an ancient peneplain it is necessary to restore in imagination the topography of the region as it existed in the later stages of the peneplain—that is, the topography to which the ancestral drainage system of the Colorado adjusted itself, and this restoration can be made only by careful detailed study. A study of the structural irregularities that date back to the time of the great denudation may afford a partial restoration of the ancient topography. Even the smallest folds or faults may have influenced the adjustment of the drainage by exposing strata of unequal resistance. Since practically all the Permian and higher strata that may have affected this adjustment of the drainage have been removed by erosion, it is obvious that

these structural irregularities are open to study only in the Paleoz rocks of the present plateau surface. The writer of this report belie that such detailed study may show that the course of Colorado Ri between Kanab Creek and the Little Colorado, at least, is related to li of structure. Davis[1] has shown that such a relation probably exi in the Kaibab division immediately west of the Little Colora

If similar speculation concerning the Bright Angel and Shinu quadrangles is undertaken, it seems significant that the northweste course of the river is parallel to the strike of the northeastwa dipping flexures of the Coconino fold and of the West Kaibab fau The great loop of the river around Powell Plateau is a local defl tion from this general northwesterly course and it is of interest note that just beyond the boundary of the quadrangle, west of t end of Alarcon Terrace, there is a faulted flexure which trends nor east-southwest and resembles on a smaller scale the West Kaib faulted flexure in Muav Canyon. The river apparently flowed we ward until it encountered this displacement, and its course was th deflected toward the north and northeast, possibly following a b of weak Permian rocks on the thrown side of the displaceme Doubtless the river was held up for a time at this displacement, a the loop around Marcos Terrace may represent a meander, sub quently entrenched, which dates back to that time.

It is now thought that the greater lines of displacement of t Grand Canyon district were blocked out in the first broad uplift th started the erosion known as the great denudation. More and m evidence has been found of movements that have taken place alo these lines at intervals throughout all succeeding time. Each su cessive faulting is correlated with a fresh uplift and a revival of t forces of erosion, necessitating the recognition of more and m cycles in the erosional history of the region.

An interesting feature of these displacements is their location up ancient lines of displacement in the basement rocks. This coin dence is the rule in the Kaibab division, as has been shown in t bulletin, and it therefore seems probable that it applies to oth faults in the district whose prolongation into the basement rocks c not be studied. The history of the displacements thus has its beg ning in the mountain-making movements of Algonkian time.

The dating of the numerous events of the complex erosional histo in geologic time is the most difficult riddle of the plateau proble A discussion of this subject has no place in the present report, for t Shinumo quadrangle affords no evidence whatever concerning A brief outline, however, will show how complex the interpretati has become since the publication of Dutton's monograph.

[1] Davis, W. M., An excursion to the Grand Canyon of the Colorado: Harvard Univ. Mus. Comp. Z Bull. 38, geol. ser., vol. 5, No. 4, pp. 164-165, 1910.

A summary of the Tertiary history as worked out by Dutton is as follows:

I. The period of great denudation, lasting until the close of the Miocene.
II. Uplift by folding (?) and faulting at close of Miocene.
III. Canyon cycle of erosion:
(a) Cutting of outer gorge of Grand Canyon during the Pliocene.
(b) Uplift by faulting at close of Pliocene.
(c) Cutting of inner gorge of the canyon during the Quaternary.

The following summary, given by Robinson [1] in a recent publication, is the most recently published interpretation of the Tertiary history. The dates of the events are assigned tentatively by that writer:

I. Period of folding and flexing during the later half or at the close of the Eocene.

II. Erosion period during the Miocene.

III. First period of faulting at close of the Miocene. A period of extensive faulting. It is correlated with the faulting that gave rise to the Basin Ranges of southern Nevada as tilted block mountains.

IV. The peneplain cycle of erosion during the Pliocene. The Miocene and Pliocene erosion, which are considered as constituting the later and greater part of the period of the great denudation, closed with the widespread development of a peneplain. This is correlated with the mature topography and local peneplains of the Basin Range country of southern Nevada and of Arizona. Relief produced by previous faulting (III) largely and at some localities entirely obliterated. Widespread volcanic activity, marked by the eruption of basalt, occurred shortly after the development of the peneplain and most probably while the region still stood close to sea level.

V. The second period of faulting at the close of the Pliocene. Movements probably of less magnitude than those of the first and third periods.

VI. The post-peneplain cycle of erosion during the first part of the Quaternary. Widespread stripping of Permian and Triassic strata and development of a mature topography of low relief, principally on the upper Aubrey limestone, at a horizon ranging from zero to 1,000 feet below the level of the peneplain. Further retreat of the high cliffs on the north and east sides of the district. Land stood at no great height above the sea.

VII. The third period of faulting, with broad regional uplift, during the middle or latter part of the Quaternary. Region raised from 4,000 to 6,000 feet above the position it occupied at the close of the post-peneplain cycle of erosion.

VIII. The canyon cycle of erosion during the latter part of the Quaternary. Marked by the development of a canyon system of drainage of extreme youthfulness. Refreshing of cliff profiles. Erosion otherwise very slight. Colder atmospheric conditions prevailed during part of this cycle, at least as indicated by the existence of a small glacier on San Francisco Mountain.

SCENIC INTEREST OF THE SHINUMO QUADRANGLE.

The views from the northern wall of the Grand Canyon in the Shinumo quadrangle have long been famous through the descriptions of Dutton.[2] The most celebrated outlook is Point Sublime, the promontory that forms the eastern arm of the Shinumo Amphi-

[1] Robinson, H. H., A new erosion cycle in the Grand Canyon district, Arizona: Jour. Geology, vol. 18, No. 8 (Nov.-Dec., 1910), pp. 763ff.

[2] Tertiary history of the Grand Canyon district: U. S. Geol. Survey Mon. 2, chaps. 8 and 9, 1882.

theater. The view from this point is the subject of the three m nificent panoramic drawings by Holmes which illustrate that part Dutton's monograph that is devoted to the scenery of the cany

A scarcely less comprehensive view may be obtained from Ha supai Point (Pl. VII, B, p. 22), on the south side of the canyon. T view within the canyon itself from this point is even more extens than that from Point Sublime, directly across the canyon. Po Sublime, however, like all points on the northern rim in the Kail division, has the advantage of greater altitude, which extends t outlook far over and beyond the southern rim of the canyon.

By far the most interesting scenic ground in the quadrangle is Pow Plateau (Pl. IV, A, p. 18), on the north side of the canyon, accessi by trail from the Muav Saddle. The scenic advantage possessed this great butte is due to its peculiar situation with reference to t course of the Grand Canyon and to its great altitude. As it l almost in the middle of the canyon, just at the elbow of the gr bend where the general course of the river changes from northwest southwest, directions maintained in either direction for over 50 mil the views from the north and south ends of the high eastern porti command a greater stretch of the interior of the canyon than can seen from any other place in the region. And since this eastern p tion of the plateau is higher than any land in the quadrangle outs of the Kaibab, it is possible to obtain from these two places an o look in every direction except to the northeast over an expanse country extending nearly a hundred miles to the horizon and incl ing the greater part of the Grand Canyon district.

The outlook from Dutton Point, at the south end of Powell Plate includes the entire Kaibab division of the canyon, seen along t very center of the pathway of the river. Below, on the northea is Muav Canyon, where the consequences of the West Kaibab fa are clearly revealed. Directly below, to the east, in the interior the canyon, is the wedge of Unkar strata about the mouth of t Shinumo. To the south, in the canyon, the topography of the w is changing from east to west, the Esplanade appearing and t Tonto platform fading gradually. Beyond the southern wall t Coconino Plateau slopes away from the canyon rim, merging gradua into the broad expanse of the San Francisco Plateau, upon wh surface the San Francisco Mountain volcanic group is in full vi 80 to 100 miles away.

The north end of Powell Plateau lies just beyond the north border of the map. Here the outlook is still more extended. To t southwest the canyon is visible through the Kanab division for miles; beyond are the white outer walls of the outer canyon in t Uinkaret and Shivwits plateaus. South of the canyon the S Francisco Plateau stretches far away into central Arizona; across

may be seen the walls of Cataract Canyon. North of the Grand Canyon lies the surface of the Kanab Plateau, broken only by the gorge of Kanab Creek; along the western border of the Kanab Plateau, beyond the mouth of Toroweap Valley, rise the mountains of the Uinkaret, a group of lava flows and recent cinder cones dominated by Mount Trumbull; many of the cinder cones are clearly visible. Along the northern border of the Kanab are the cliffs and terraces of Mesozoic strata, beginning with the Vermillion Cliffs, composed of Triassic strata, and receding step by step to Pink Cliffs, which are composed of Tertiary strata. To the northwest the promontories of Vermillion Cliffs fade below the horizon 100 miles away.

In the foreground, directly below, is Tapeats Amphitheater, an expanse of Esplanade 12 miles across, trenched by the single gorge of Tapeats Creek and by two arms of the great lateral gorge which runs northward from Muav Saddle across the head of the Amphitheater in the line of the West Kaibab fault. Along Colorado River above the mouth of Tapeats Creek may be seen the mass of Unkar strata which lies in the Lower Granite Gorge and represents the prolongation of the Shinumo wedge northwestward underneath Powell Plateau.

To the geologist these two views from Powell Plateau are encyclopedic. The rocks that are visible represent in turn a portion of every great geologic age, and the stratigraphic position of each system of rock is apparent at a glance. Every great earth-making process is illustrated; sedimentation by a thickness of over 16,000 feet of unaltered strata reaching from Algonkian to Tertiary; regional metamorphism by the Archean rocks; contact metamorphism by certain Unkar strata; vulcanism by deep-seated invasions in the Archean, by intrusive sheets in the Unkar strata, and by surface eruptions in the San Francisco Mountains and the hills of the Uinkaret Plateau; deformation by the mashed and crumpled Archean rocks, by the faulted Algonkian rocks, and by the great displacements that traverse the Paleozoic strata. Perhaps the most impressive record of all is that of the processes of uplift and erosion—the ancient cycles denoted by the unconformities that separate the systems of rock; the later cycles by the removal of vast thicknesses of strata and the production of the surface of the region in its present aspect.

The panorama is probably the most complete geologic revelation in the world.

COPPER DEPOSITS OF THE SHINUMO QUADRANGLE.

Occurrence.—With one exception all the copper deposits in the quadrangle are found in the Archean and Algonkian rocks in the depths of the canyon.

History.—The discovery and exploration of the deposits is the w(of Mr. W. W. Bass and Mr. John Walthenberg. A large amount prospecting has been done and claims have been located in Cop] Canyon, Bass Canyon, Granite Gorge near Cable Crossing, Shinu Canyon between White Creek and Flint Creek, along the line of West Kaibab fault, and on Muav Saddle.

The most valuable bodies of ore so far found are in Copper Cany from which about 25 tons of ore were taken in 1908. The ore carried to the rim of the Grand Canyon on burros, and hauled the 20 miles by wagon to Grand Canyon, a station on the Grand Can Railway, of the Santa Fe system. Some exploratory work has b done at the other localities, but so far no attempt has been made take out ore for shipment.

Geology.—The claim in the Muav Saddle is the only one in Paleozoic rocks. It is just at the point where the trail up M Canyon enters the saddle, at an elevation of 6,700 feet. Some cop mineralization occurs along the contact of the Supai formation Coconino sandstone, where the beds are shattered by the W Kaibab fault, and this mineralized zone is now being explored by open cut. The copper here is doubtless of the same age and origin that of the deposits found on the surface of Kaibab and Cocon plateaus in other parts of the Grand Canyon district.

The deposits in Copper Canyon are, in method of occurrence, a type of all the deposits in the Archean and Algonkian rocks in quadrangle. As they are the only ones now accessible to undergrou study a description of them will also serve in a general way for th at the other localities.

The country rock of the interior of Copper Canyon beneath Paleozoic is the Vishnu schist, of the Archean system. At the end the great pre-Cambrian erosion the basal strata of the Unkar gr of the Algonkian extended part way across the Granite Gorge Copper Canyon, terminating there as the apex of the Algonkian wed Only a few layers of these strata in that locality, however, h escaped the present cycle of erosion. These lie high up under cliff of Tapeats sandstone, in the eastern wall of the Granite Gorg Copper Canyon.

The ore bodies in Copper Canyon all lie in the rocks of the Vis schist which in this locality are quartz-mica schists and pegmati The ores are found in two main veins, which will be described.

The outcrop of the first vein runs northwestward across the Gra Gorge of Copper Canyon. The vein is almost vertical, dipp slightly southwestward. On the east side of the creek, at the bott of the canyon, a tunnel has been driven in southwestward for o 100 feet along the strike of the vein. This tunnel is about half a n from Colorado River, at an elevation of about 2,800 feet. A verti

shaft has also been sunk 50 feet on the vein which it followed down the dip from the surface outcrop. This shaft intersects the tunnel at a point 15 feet below the surface of the ground and 25 feet from the mouth of the tunnel. All the ore that has been taken from Copper Canyon for shipment has come from these workings.

The ore minerals of the vein in this locality are cuprite, bornite, and chalcocite. The first two minerals make by far the greater proportion of the ore mined. The chalcocite has come from the most recent workings at the bottom of the shaft. The gangue of the vein is chiefly brecciated mica schist cemented by milky quartz and some calcite. The vein shows the usual pinches and swells, and averages about 1 to 2 feet in width. The minerals on the outcrop of the vein are considerably weathered, making incrustations of malachite and green silicate of copper.

The second vein crosses the creek bed a few hundred feet north of the first vein. Its strike is nearly east and west and its dip is about 60° N. About 200 feet above the level of the bed of the creek where it is crossed by the vein a tunnel, known as the Hakataia tunnel, has been driven westward along the strike of the vein for 75 feet. The vein at the tunnel in about a foot wide. The ore minerals taken from the tunnel include cuprite, bornite, chalcopyrite, and argentiferous galena. The gangue is quartz. Near the surface the ores are leached of their values by weathering but grow richer underground.

The two veins converge toward the west in the western wall of Copper Canyon. Their inclined dip would also cause them to converge upward on the eastern side of the canyon, but this part of their apex has been removed by erosion.

The second vein was traced upward in the eastern wall of Copper Canyon to the base of the Unkar strata and was found to be on the prolongation downward into the Archean rocks of one of the Algonkian faults. It is therefore a simple mineralized fault fissure. The first vein was similarly traced upward but was found to be truncated by the pre-Tonto unconformity just beyond the apex of the Algonkian wedge, so that its relation to the Algonkian faulting could not be positively determined. It represents, however, a filled fissure produced by a normal fault of small throw, the evidence of which is found in the offset of certain pegmatite veins that are sheared by the fault. This fissure is doubtless the downward prolongation of an Algonkian fault like that on which the other vein is located.

All the other deposits in the Archean and Algonkian rocks occur either in similar fissure veins, which represent the mineralized fault planes of normal Algonkian faults, or in the zone of shattering along the line of the Algonkian displacement of the West Kaibab fault. All the faults belong to the same period of disturbance, the one in which the great mountain-making movement came at the end of Algonkian time.

Age.—The primary ore deposition undoubtedly occurred in Algonkian time, as all the ore-bearing fissures are truncated by the unconformity at the base of the Paleozoic.

Origin.—The origin of the primary ore deposition is not clear. The event with which it is obviously connected is the Algonkian mountain-making movement, but the specific causes that set up the circulation of the mineral-bearing solutions are a matter of speculation. It is possible that some sort of a genetic connection may have existed between the mineral-bearing solutions and the igneous activity manifested by intrusions of diabase in the Unkar strata of the Shinumo region, although it is clear that the intrusions in this locality were earlier than the faulting that gave rise to the mineral-bearing fissures.

Value.—The deposits in Copper Canyon are locally of high grade, but not enough work has been done to give an accurate idea of their extent and quantity.

INDEX.

A. Page.

Acknowledgments to those aiding........... 15
Algonkian rocks, occurrence and character of........................ 30-31, 37-60, 61
Altitudes, data on........................... 24-25
Archean rocks, occurrence and character of. 29-30, 31, 32-37
Asbestos, occurrence of.................. 13, 58-59
 origin of................................. 59-60
Asbestos mine, section at..................... 58
Aubrey group, distribution and character of. 68-71
 geologic relations of....................... 61
 subdivisions of............................ 61, 68
Aztec Amphitheater, altitude of............. 25

B.

Bass, W. W., copper prospecting by......... 94
Bass Camp, location of...................... 11-12
Bass Canyon, cirque at head of....... 22 (Pl. VII)
 folds and faults in............ 78, 78 (Pl. XVI)
 rocks in...................... 40, 55 (Pl. XIV)
 section in................................. 65
 tank in .... 11 (Pl. I)
Bass limestone, character of..... 30 (Pl. IX), 43-48
 deposition of............................. 81
 geologic relations of...................... 41
 section of.......................... 44-46, 55, 58
 views of........................... 38 (Pl. X), 39 (Pl. XI), 54 (Pl. XIII), 86 (Pl. XVIII)
Bedrock Tank, view at................... 11 (Pl. I)
Bibliography................................. 13-15
Bright Angel Creek, rocks on........ 38, 38 (Pl. X)
Bright Angel fault, location of............... 78
Bright Angel shale, deposition of............ 84
 distribution and character of...... 30 (Pl. IX), 62-64, 74
 fossils in................................ 64, 84
 section of................................. 63
 views of............... 20 (Pl. V), 38 (Pl. X), 39 (Pl. XI), 79 (Pl. XVII), 86 (Pl. XVIII)
Burro Canyon, view in .... 79 (Pl. XVII)
Butte fault, character of..................... 79

C.

Cable crossing, description of................ 11, 16 (Pl. III), 54 (Pl. XIII)
Cambrian system, distribution and character of............................ 31, 61-65
Camps, locations of......................... 11-12
Canyons, description of...................... 17
Carboniferous rocks, occurrence and character of............................ 31, 66-71
Carkhuff, N. W., photographs by............ 20, 21, 38, 39, 54, 79, 86
Cataract Canyon, location of................. 19
Chuar group, distribution of.............. 37, 38, 40
 geologic relations of...................... 7-8
 See also Grand Canyon series.

Page.

Climate, character of......................... 26-27
Coconino fold, description of................ 78-79
Coconino Plateau, climate of................. 26-27
 description of...................... 19, 24-25, 27
 location of............................... 17
Coconino sandstone, deposition of........... 85
 distribution and character of.... 30 (Pl. IX), 69
 thickness of............................. 72-73
 views of .... 20 (Pl. V), 21 (Pl. VI), 38 (Pl. X), 39 (Pl. XI), 86 (Pl. XVIII)
Colorado Plateau, description of............. 15-16
Colorado River, canyons of.................. 17
 cutting of......................... 87-88, 89-90
 description of........................... 22-24
Copper, deposits of.......................... 93-96
Copper Canyon, copper in................... 94-95
Crystal Creek, rocks on...................... 38

D.

Darton, N. H., cited.......................... 68, 69
 work of.................................. 60
Darwin Plateau, altitude of.................. 25
Davis, W. M., cited...................... 74, 89-90
Denudation, the great, occurrence of.... 87, 88, 90
Diabase, age of.............................. 60
 asbestos in. *See* Asbestos.
 invasion of............................... 83
 lower contact of................. 55 (Pl. XIV)
 metamorphism of......................... 57-58
 occurrence and character of............. 55-60
 views of......................... 639 (Pl. XI), 52 (Pl. XII), 54 (Pl. XIII), 55 (Pl. XIV), 64 (Pl. XV), 79 (Pl. XVII), 86 (Pl. XVIII)
Diller, J. S., on asbestos............... 13, 14, 58-60
Dox sandstone, character of........ 30 (Pl. IX), 53
 deposition of 82
 geologic relations of...................... 41
 section of................................ 53, 55
 views of............ 39 (Pl. XI), 54 (Pl. XIII)
Dutton, C. E., cited............ 20, 38-39, 73, 89-91
 work of............................... 7, 13, 14
Dutton Point, view from.................... 92

E.

Echo Cliffs, location of....................... 17
Erosion, record of.................... 22 (Pl. VII), 26-27, 30, 70, 78 (Pl. XVI), 80-88
Esplanade, description of....... 18, 21-22, 25, 27-28
 origin of................................. 73-75
 view of .... 21 (Pl. VI)
Evans, R. T., work of....................... 8

F.

Faulting, description of...................... 75-80
 effect of, on topography.................. 79-80
 occurrence of................ 79 (Pl. XVII), 83
Field work, extent of........................ 18

Page.

Folds, description of.......................... 76–80
views of.......... 78 (Pl. XVI), 79 (Pl. XVII)
Fossil Mountain, rocks of.................... 70
section near.............................. 70–71
view of........................... 22 (Pl. VII)
Fossils, occurrence of........................ 84, 86
See also particular formations.

G.

Geography, description of.................. 11–12
Geologic history, account of. 80–91, 86 (Pl. XVIII)
Geologic map of Shinumo quadrangle........ Pl. I, in pocket.
Geology, description of..................... 20–75
Gilbert, G. K., work of...................... 15, 60
Girty, G. F., fossils determined by.......... 71
Goldthwait, J. W., and Huntington, E., on Colob sandstone................ 85
Grand Canyon, age of........................ 88
climate in................................ 25–26
description of..................... 17–18, 21–25
exploration in............................ 7–8
history of................................ 89–91
map of...................... 8, Pl. I, in pocket.
strata revealed by........................ 7
travel in...................... 11 (Pl. I), 11–12
Grand Canyon district, description of........ 16–21
Grand Canyon series, age and correlation of.. 54–55
distribution and character of............ 37
geologic relations of...................... 7
history of................................ 80–83
intrusions in............................. 55–60
name of................................... 37
structure of.............................. 39, 40
unconformity in........................... 37
See also Unkar group; Intrusive diabase.
Granite Gorge, description of.............. 18, 21, 23
rocks of............ 23, 29, 32, 35, 36, 38, 39–40, 61
views in............ 16 (Pl. III), 28 (Pl. VIII)

H.

Hakatai Canyon, rocks in................ 43, 57–58
section in................................ 48
Hakatai shale, character of...... 30 (Pl. IX), 48–51
deposition of............................ 81–82
geologic relations of..................... 41
section of............................ 48–50, 55
views of............... 38 (Pl. X), 39 (Pl. XI), 52 (Pl. XII), 54 (Pl. XIII), 64 (Pl. XV), 79 (Pl. XVII), 86 (Pl. XVIII)
Havasupai Point, description of............ 24–25
views of and from......................... 21, 21 (Pl. VI), 22 (Pl. VII), 92
Hindu Amphitheater, rocks in.............. 38
Holy Grail Temple, description of........... 25
Hoodoos, occurrence of.......... 70, 78 (Pl. XVI)
Hotauta Canyon, rocks in........ 38 (Pl. X), 42–47
section in............................ 42, 43–46
Hotauta conglomerate, character of.......... 30 (Pl. IX), 42–43
deposition of............................ 81
geologic relations of..................... 41
Huethawali, Mount, view of.......... 22 (Pl. VII)
Huntington, E., and Goldthwait, J. W., on Colob sandstone................ 85
Huxley Terrace, view of............. 22 (Pl. VII)

I. Page

Indian ruins, distribution and character of... 28–

K.

Kaibab limestone, character and distribution of............. 16, 21, 30 (Pl. IX), 70–
deposition of
fossils of
pinnacles of...................... 78 (Pl. XV
section of.............................. 70–
thickness of............................ 72–
views of............... 18 (Pl. IV), 21 (Pl. VI
39 (Pl. XI), 86 (Pl. XVII
water in, flow of....................... 27,
Kaibab Plateau, climate on
description of..................... 17, 18, 19,
Grand Canyon in.................... 18, 21,
Kanab Plateau, description of............ 17, 18,
Grand Canyon in

L.

Lava, deposition of
Lee, W. T., cited.......................... 67–
Literature, list of......................... 13–
Location of quadrangle..................... 11,
Lower Aubrey sandstone, changed name of..

M.

Map of Shinumo quadrangle... 8 Pl. I (in pocke
Map, index, showing location of quadrangle.
Marble Canyon, description of
Marble platform, description of
Matthes, F. E., work of
Mesozoic rocks, deposition of
Monadnock, survival of
Monadnock Amphitheater, rocks of....... 40, 61–
Muav-Flint canyon, description of
faults in.................................. 75–
rocks of................. 33, 39, 40, 64 (Pl. X
Muav limestone, deposition of
distribution and character of 30 (Pl. IX), 64–
section of
thickness of............................. 72–
views of.. 20 (Pl. V), 39 (Pl. XI), 54 (Pl. XIII
64 (Pl. XV), 79 (Pl. XVII), 86 (Pl. XVII
Muav Saddle, copper in
description of
view of............................ 18 (Pl. I

N.

Needle Mountains group, character and correlation of......................... 54–
Noble, L. F., work of
Nomenclature, changes in

O.

Ottoman Amphitheater, rocks in

P.

Paleozoic rocks, displacements of............ 78
occurrence and character of........... 31, 61
previous work on
thickness of............................ 71
variation in, effect of................ 73
Pegmatite, distribution and character of..... 36
Physiography, account of.................... 15

Page.
Plateaus, description of 17
problem of 88–91
Point Sublime, description of 24
view from 91–92
Powell, J. W., cited 39, 89
work of 7
Powell Plateau, climate of 26
description of 19, 20, 27
flexures in 78
views on .... 18 (Pl. IV), 92–93
Proterozoic rocks, occurrence and character of. 32–60

Q.

Quartz diorite, distribution and character of. 35

R.

Rainbow Plateau, valleys of 20
Rainfall, occurrence of 25–26
Ransome, F. L., cited 35, 57, 65
preface by 7–9
Redwall limestone, deposition of 84
distribution and character of. 30 (Pl. IX), 66–68
fossils in 67–68
geologic relations of 61
thickness of 72–73
views of.... 20 (Pl. V), 38 (Pl. X), 39 (Pl. XI), 54 (Pl. XIII), 79 (Pl. XVII), 86 (Pl. XVIII)
Robinson, H. H., cited 75, 91
Rock formations, age and character of 29–32
columnar section of .... 30 (Pl. IX)

S.

San Francisco Plateau, location of 18
Scenic features, interest in 91–93
Sedimentary and erosional record, data of.... 80–88
Shinumo Amphitheater, description of 22, 24, 25, 28, 79
Indian ruins in 28–29
Shinumo Creek, canyon of .... 28 (Pl. VIII), 64 (Pl. XV)
canyon of, section in 51–52, 53, 57
description of 23, 24
rocks on .... 38, 52 (Pl. XII), 55 (Pl. XIV), 64 (Pl. XV)
section on 42
Shinumo quartzite, character of.. 30 (Pl. IX), 51–53
deposition of 82
geologic relations of 41
monadnocks of 83, 84
section of 51–52
views of .... 38 (Pl. X), 39 (Pl. XI), 52 (Pl. XII), 64 (Pl. XV), 79 (Pl. XVII), 86 (Pl. XVIII)
Shinumo wedge, description of 40, 41, 77
See also Unkar wedge.
Shivwits Plateau, description of 17, 19
Slate Creek, fault on 78
Snow, occurrence of 25
Snuffy limestone, distribution and character of 74
views of .... 79 (Pl. XVII), 86 (Pl. XVIII)
Springs, source of 27
Structure, description of 75–80
sections showing .... Pl. I, in pocket.
Supai formation, deposition of 84–85
distribution and character of .... 30 (Pl. IX), 68–69, 74
sandstone of 68–69
shale of 67
thickness of 72, 73
views of .... 20 (Pl. V), 21 (Pl. VI), 38 (Pl. X), 39 Pl. XI), 86 (Pl. XVIII)

T.

Tapeats Creek, description of 22
Tapeats sandstone, deposition of 84
distribution and character of.. 30 (Pl. IX, 61–6
section of 62
thickness of 72–73
views of .... 20 (Pl. V), 38 (Pl. X), 39 (Pl. XI), 54 (Pl. XIII), 55 (Pl. XIV), 79 (Pl. XVII), 86 (Pl. XVIII)
Tertiary rocks, deposition of 86
Tertiary time, history of 91
Timber, growth of 27–28
Tonto group, deposition of 83–84
distribution and character of 61–65
Tonto platform, description of 18, 22, 25, 28
origin of 73, 75, 76
view from .... 18 (Pl. IV), 20 (Pl. V)
Tonto sandstone, changed name of 32
Tonto shale, changed name of 32
Trails, routes of 11–12, 18, 19, 29

U.

Uinkaret Plateau, description of 17, 19
Unconformities, occurrence and character of .... 30 (Pl. IX), 30, 31, 61, 65–66, 84, 86 (Pl. XVIII), 87–88
Unkar group, character of 40–53
deposition of 81–83
geologic relations of 7–8
intrusive diabase associated with 55–60
See also Diabase.
name of 37
section of 42, 44–53
structure of 39–40
subdivisions of 41–42
See also particular subdivisions.
views of.... 16 (Pl. III), 20 (Pl. V), 38 (Pl. X)
Unkar monadnock, description of 61, 62
Unkar Valley, section in 53–54
Unkar wedge, faults in .... 64 (Pl. XV), 77–78, 79 (Pl. XVII)
view of .... 18 (Pl. IV)

V.

Valleys, beheaded, occurrence and character of 20
Vegetation, character of 27–28
Vishnu Creek, rocks in 38
Vishnu schist, age and correlation of 35
distribution and character of. 30 (Pl. IX), 32–35
geologic relations of 7–8, 29, 31
intrusions in 35–37
name of 32
origin of 34–35, 80
types of 33–34
views of .... 16 (Pl. III), 20 (Pl. V), 38 (Pl. X), 39 (Pl. XI), 86 (Pl. XVIII)

W. Page.

Walcott, C. D., cited 32, 37, 65-66
work of.................................. 7, 15, 60
Walthenburg, John, copper prospecting by.. 94
Warping, occurrence and character of........ 20-21
See also Faulting; Folding.
West Kaibab fault, age of...............
description of.......................
effect of...............................
line of.................................
Wheeler fold, description of.......... 78
79